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Research in High-Energy X-Rays

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In recent years the invention and development of high-energy electron accelerators have extended the frontier of available X-rays to the region of thousands of millions of electron volts. High-energy X-rays have several unique properties that make them extremely useful not only in nuclear physics but in radiation therapy and industrial radiography. To assist the scientific, medical, and industrial users of high-energy electron accelerators, the National Bureau of Standards established a betatron laboratory in 1950. The laboratory contains a 50-MeV betatron and a 180-MeV synchrotron, which are being used for the development of measurement techniques and for basic research into the physical characteristics of high-energy X-rays, including their interaction with matter. A laboratory staff of sixteen carries out the high-energy programme.

50-MeV Betatron

The 50-MeV betatron accelerates electrons by means of magnetic induction. It consists essentially of a 12-ton alternating-current electromagnet, the core of which is encircled by the main coil and also by a doughnut-shaped vacuum chamber. A current of 50 kV electrons is injected tangentially into the vacuum chamber when the magnetic field has just passed its zero value. As the main coil current increases, the electrons in the vacuum chamber, acting as a secondary winding of a transformer, are accelerated to higher energies. At any instant during their acceleration up to 50 MeV, they may be made to strike an internal target, thus producing a pulse of X-rays with a time width of approximately 10 microseconds. The repetition rate of the betatron X-rays is 180 pulses per second.

The Bureau has constructed a new type of energy selector which provides an extremely stable and reproducible energy adjustment for the X-rays. It permits certain types of experiments to be performed with an energy stability of the order of 20 kV out of 40 MV. This device consists essentially of a special transformer which produces a pulse when the main magnet current reaches a preselected value. The pulse, properly amplified, is then used to deflect the electrons from their orbit against a target.

In order to extend the usefulness of the betatron, considerable effort has been applied towards the removal of the electrons from the betatron in a beam. For this purpose, the Bureau developed a magnetic extractor which makes it possible to study the direct electron interaction with matter at a position remote from the betatron but near to the electron target.

The extractor employs a specially constructed coil inserted into the vacuum chamber in a position to which the electrons can be deflected. A pulsed current through this coil produces a local magnetic field of 5500 gauss, which is sufficient to cancel the main magnetic guiding field in that region. Furthermore, it produces a field whose entire effect increases from approximately zero to its maximum value within a distance of 1 mm. This discontinuity is necessary in order that the cancelled magnetic field be felt suddenly by the electrons as they are gradually deflected into the region of this coil. The electrons, upon reaching the region of cancelled magnetic field, travel in an approximately straight path and thereby escape from the guiding field of the magnet. The electron beam has been successfully extracted from the betatron at energies up to 24 MeV and with peak currents of the order of 5×10^{-10} A. A large magnet has also been constructed which can focus electrons with energies up to 50 MeV. This magnet, with a focal length of a few metres, will enable the electron beam to be directed against samples as small as a few millimetres in extent and will permit the use of very rare elements or separated isotopes as samples in the study of electron and X-ray effects.

180-MeV Synchrotron

The synchrotron is very similar to the betatron in appearance. However, to accelerate electrons to the region of hundreds of millions of volts, it is generally more economical to employ an oscillating tangential electric field at one point of the circular electron orbit. This electric field in the NBS synchrotron has a frequency of 57 megacycles per second and is synchronised with the frequency of revolution of the electrons in their orbit of 33 in. radius. Each time the electrons travel through the oscillator section, they experience an accelerating impulse. Since the electrons travel most of their path above 2 million volts, they have an approximately constant velocity, ranging between 98 and 99. 99% of the velocity of light. Therefore, there is no need to provide a variable frequency. Acceleration up to 2 MeV is produced by magnetic induction around a flux bar in the centre of the orbit. The magnet, which provides the guiding field and the central acceleration flux, weighs 150 tons and operates at a frequency of 60 cps. Thus, 60 short bursts of X-rays are produced each second. An extra set of coils on the synchrotron is used to deflect the electrons against the internal X-ray target at any desired energy below 180 million volts. This provides the versatility necessary to determine various effects at different operating energies.

Crystal Spectrometer

The X-rays emerging from the betatron and synchrotron comprise an entire spectrum of photon energies, ranging from the kilo-electron-volt region up to the kinetic energy of the electron which produced the X-rays. The spectrum has a characteristic shape, depending upon such factors as the target material and the intervening absorbing material. In many experiments, individual photons of a particular energy must be selected from this spectrum. Until several years ago, the only suitable instruments in the high-energy range were the pair and Compton spectrometers, which are relatively unwieldy and inefficient. These detectors depend upon the measurement in a magnetic field of the energy of pair or Compton electrons produced by the X-rays in a thin radiator. They have X-ray detection efficiencies of the order of 0 001%.

In order to overcome the handicap of dealing with a multitude of photon energies with inefficient detectors,

the Bureau developed a crystal spectrometer with a photon-detection efficiency exceeding 80% and an energy resolution of 11% in the range from 0·5 to 50 MeV. The heart of this spectrometer is a large sodium iodide (thallium-activated) crystal. The dissipation of the energy of an individual photon in such a crystal produces a visible light pulse detected and measured by photomultiplier tubes. The total light output is proportional to the total energy absorbed. The crystal actually consists of two crystals, each 5 in. in diameter and 4 in. in length. It is sufficiently large for approximately all the energy of the primary X-ray photon to be absorbed within it. The spectrometer is constructed so that four 2-in. diameter photomultiplier tubes view the crystal from each end. Their outputs are added to produce one electrical pulse representative of the photon energy. The development of this crystal spectrometer has provided an approach to many experimental research problems that were formerly considered impossible to solve, because of the low detection efficiency of available instruments.

Pulse-Height Analyser

The wealth of information obtained from a crystal spectrometer may be obscured by the distribution of electrical pulse heights. Thus, it is necessary to separate the pulses of different heights into different recording units. However, the standard electronic circuits designed for this purpose are cumbersome and costly. The Bureau therefore developed a pulse-height analyser which is compact, economical, and particularly well suited for application to any pulsed source, such as a betatron or synchrotron.

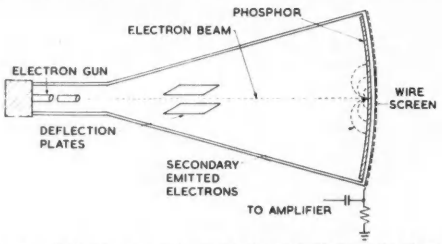


Fig. 1. **Cathode-ray tube used in the NBS pulse-height analyser.**

The NBS pulse-height analyser makes use of a cathode-ray tube (Fig. 1). An electrical voltage pulse whose height is to be measured is applied to the vertical deflection plates, thus charging the phosphor in a line whose length is proportional to the voltage pulse height. During the dead time between betatron pulses, a linear sweep is applied to the same set of vertical deflection plates; simultaneously, a set of time gates is started. When the linear sweep passes the end of the original charged line, a pulse is picked up in a wire screen covering the outer face of the cathode-ray tube. This pulse is then accepted in the time gate, which is open at that instant. Since the sweep is linear, the time of occurrence of the pick-up pulse is a measure of the pulse height of the initial pulse. Some of the advantages of the system are:—(1) A variety of pulse shapes can be accepted for measurement without special pulse-shaping networks; (2) more than one pulse occurring within a single cycle interval can be detected and measured during the off-time of the X-ray source; and (3) the circuit components are straightforward and can be inexpensively constructed. This technique is undergoing further development at the Bureau.

Nuclear Studies

The high-energy X-rays and electrons generated by the betatron and synchrotron are being used to study the interaction of these radiations with the atomic nucleus. The experiments deal with neutron thresholds and yield curves, nuclear absorption, and nuclear scattering of high-energy X-rays.

If a nucleus is bombarded with a sufficiently high-energy X-ray or electron, it is possible to break off one or more of the particles of which the nucleus is composed. This effect is being studied, using radiations from the betatron. Particular attention is being paid to the threshold for neutron production, defined as the smallest energy that must be added to a nucleus in order to eject a neutron. The threshold is determined by observing the neutron yield from a sample, as the energies of the electrons or X-rays used to bombard the sample are slowly increased. The neutron yield is measured either by observing the radioactivity often induced in the sample by the removal of a neutron, or by using a neutron detector to observe the emitted neutron directly. The ability to focus the removed electron beam from the NBS betatron onto a small spot makes it possible to use the neutron detector to make measurements of the neutron yield from samples whose size is comparable with that of the separated isotope samples available from the Atomic Energy Commission. In a carefully conducted experiment, the threshold energy approximately fixes the energy difference or the mass difference between two neighbouring isotopes.

The absorption and scattering studies are " optical " experiments, using photons with energies up to 30 MeV (wavelengths down to 4×10^{-12} cm). These experiments are analogous with some of the early experiments carried out in the field of atomic spectroscopy. The experiments in the visible light range gave information of considerable value in building up a physical picture of atomic systems. The percentage resolution obtainable with the sodium iodide scintillation spectrometer used in the nuclear studies at the betatron laboratory is an order of magnitude less than that obtainable with the spectrometer used for making observations with visible light. This of necessity requires that the nuclear measurements be averaged over relatively broad energy intervals. In spite of this, the nuclear experiments are providing valuable information about the position and strength of the energy levels in various nuclei.

The nuclear absorption experiments correspond to the studies made with visible light of the dark absorption lines and bands found in a white-light spectrum after its passage through vaporised material. In the nuclear experiments the X-ray spectrum produced by the betatron or synchrotron is used as a " white-light spectrum." These X-rays are passed through as much as nine feet of material and the transmitted spectrum shows dips " bands " in the energy region of strong nuclear absorption by the material under investigation. A study of the position and magnitude of the dips gives information concerning the energy and strength of the nuclear levels responsible for the stronger nuclear absorption effects.

The nuclear scattering experiments constitute a study of the anomalous dispersion or the fluorescence of various atomic nuclei. These effects are being observed with photons having energies greater than 5 MeV. The probability (cross-section) for the elastic scattering of high-energy photons is being measured for various nuclei as a function of photon energy from about 5 to 30 MeV. Optical theory predicts that there will be an elastic scattering associated with an absorption of photons. The absorption and scattering are related by general conservation laws. These relations are being verified for the nuclear absorption and scattering of photons by comparing the results obtained in the scattering experiment with the variable absorption data. In the energy regions where the nuclear absorption of photons does not lead to particle emission, and where the nuclear absorption is too small to be measured by absorption techniques, the scattering measurements are giving valuable data, not otherwise obtainable about

the nature of nuclear energy levels. These experiments, together with the nuclear absorption experiments, are providing information which aids in understanding the nature of the energy level systems of nuclei at excitations from 5 to 30 MeV.

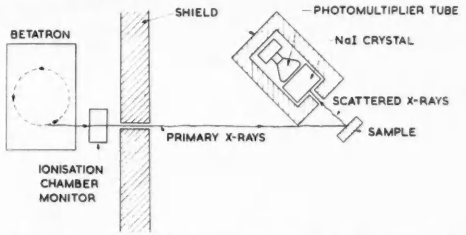


Fig. 2. **Schematic diagram of the NBS elastic scattering experiment.**

Fig. 2 is a schematic diagram of the NBS elastic scattering experiment. The primary X-rays, consisting of an entire spectrum with a maximum energy E_0, are scattered from the sample. The sodium iodide crystal and spectrometer are biased to detect only those photons with energies close to E_0, i.e., those photons which are scattered from the nucleus with very little loss of energy.

Basic Research for Medical Applications

New and improved methods for the treatment of cancer and related diseases are constantly being developed. Several hospitals have initiated treatments using the high-energy X-rays from betatrons and synchrotrons. The NBS betatron laboratory is aiding in this work by providing some of the basic measurements required for successful therapy. High-energy X-rays differ from conventional low-energy X-rays in the distribution of the energy absorbed in human tissue. Low-energy X-rays produce a maximum effect at the surface of the skin, with a decreasing effect at greater depths. High-energy X-rays, on the other hand, have only a small effect at the surface, but this effect increases to a maximum at a depth in the tissue dependent upon the X-ray energy. Such an absorption effect is obviously better suited than low-energy X-rays for treatment of deep-seated tumours. The relatively small amount of scattering in the high-energy X-rays also permits greater concentration of the effect of the X-rays on a tumour.

Experiments have been carried out by the Bureau to provide accurate descriptions of these characteristics of high-energy X-rays. In one case, a water bath was used to simulate a patient, and a small ionisation chamber and scintillation detector were moved to various locations to map out the distribution of ionisation throughout the water. This experiment was performed at several different operating energies. From these and several subsidiary experiments, basic quantities were determined, such as the ratio of energy absorbed in the water to the ionisation produced in an air cavity located at that position. For the case of betatron X-rays dissipating their energy in water, this ratio is about 90 ergs gr for 1 electrostatic unit of ionisation per cubic centimetre. The importance of this ratio lies in the fact that X-ray dosage is ordinarily measured with small air-cavity ionisation chambers, while the quantity of clinical interest is the energy absorbed per gram of tissue.

Improved Techniques for Industrial Radiography

The problem of detecting small flaws in large metallic castings or in assembled mechanisms is of prime importance to industry. Low-energy X-ray radiography has been used to inspect metallic parts for many years, but it has certain natural limitations for this work. The strong absorption of low-energy X-rays by most materials sharply limits the thickness of material that can be penetrated in practice. Also, the large amount of scattering produced in the material being examined and, in most cases, the large size of the focal spot of the X-ray tube have limited the amount of detail which can be seen.

These limitations are much less severe for the high-energy X-rays produced by a betatron. Since most materials are much more transparent to high-energy X-rays, thicker specimens may be examined. The high forward momentum of this radiation greatly reduces diffusion of the X-ray image by scattering and, in conjunction with the small betatron focal spot, produces sharper radiographs, permitting the detection of more minute flaws. For these reasons, the use of high-energy X-rays for radiography of large objects has become increasingly widespread.

One of the objects of the Bureau's betatron programme is the improvement of techniques for viewing X-ray images transmitted by large objects undergoing inspection. An instrument called a "pattern amplifier" has been assembled and has been shown to have many practical applications. In its most interesting application, it acts as an X-ray image intensifier, continuously detecting, amplifying, and displaying low-intensity X-ray images transmitted by large objects.

The major component of the pattern amplifier (Fig. 3) is the converter, a large, cylindrical, thallium-activated sodium iodide crystal, which converts X-ray images into optical images. When bombarded with an X-ray beam which has passed through an object with internal structure, the crystal emits visible light. If the crystal is oriented with its flat faces perpendicular to the X-ray beam, and if it is observed along the beam axis, a visible replica of the X-ray image may be seen. The various crystal converters now being tested have diameters up to 7⅞ in. and thicknesses up to 1 in.

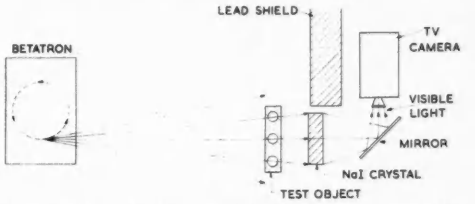


Fig. 3. **Schematic diagram of the X-ray pattern amplifier.**

The visual image may be detected in several ways. For recording purposes, it can be photographed with an ordinary camera. It may be continuously observed by eye, if proper precautions have been taken to protect the observers from radiation, or it may be observed with a remote-controlled television camera, part of a closed television chain, which transports the image to a safer position, intensifies it, and displays it on a monitor kinescope. With such an arrangement, the pattern amplifier can be used for rapid flaw inspection of large objects, or, with the incorporation of a suitable timing mechanism, for stroboscopic studies of the operation of cyclic mechanisms, such as internal combustion engines.

When the converter is viewed by a television camera specially designed for low light intensities, the pattern amplifier is sufficiently sensitive to detect X-ray images with an intensity as low as 2×10^{-5} milliwatts/cm² at the crystal. Assuming an available X-ray intensity of 1 milliwatt/cm² at a distance of 3 m from the 180-MeV synchrotron, the X-ray images produced can still be detected after the X-ray beam has been attenuated by a factor of 50,000. This means that the pattern amplifier can continuously display X-ray images seen through as much as 18 in. of steel or 7½ ft of concrete. The resolution does not appear to vary significantly for energies between 20 and 180 MeV.

X-Ray Calorimeter

The interpretation of experimental data obtained with high-energy X-rays generally depends upon an accurate knowledge of the beam intensity. It is therefore extremely important that standard methods for measuring X-ray intensities be developed. The usual method of measuring beam intensities makes use of an ionisation chamber. This method has been quite satisfactory below 2 million volts, provided that normal precautions are taken. However, for higher-energy X-rays, the interpretation of an ionisation measurement in terms of beam intensity becomes extremely difficult and contains many uncertainties. For this reason, the Bureau has been engaged in the development of a calorimeter for use as a primary standard in the measurement of high-energy X-ray beam intensities.

The NBS calorimeter consists essentially of a lead cylinder of a size suitable for absorbing most of the X-ray beam. The temperature rise in the lead cylinder due to the absorbed X-rays is compared with the temperature rise produced by a measurable quantity of electrical energy dissipated in the cylinder. The measurement therefore supplies a direct comparison between X-ray energy and electrical energy.

The lead cylinder, 4 cm in diameter and 7·5 cm in length, is gold-plated and is suspended by fine Dacron thread in a chromium-plated vacuum chamber to reduce heat losses. The entire vacuum chamber is submerged in a constant-temperature water bath. In order to detect the small temperature changes of the lead cylinder, thermistors are used whose temperature coefficient of resistance is approximately —3·6%/°C. Two such thermistors are used in the lead and are connected in a Wheatstone bridge circuit, in order to detect the minute resistance changes associated with the temperature changes in the cylinder. X-radiation power of the order of 0·1 milliwatt for 5 minutes results in a temperature rise of 2×10^{-4} °C and can readily be measured with this calorimeter to an accuracy of a few per cent.

RUSSIA

Electroless Nickel Plating

By S. M. Panchenko and M. A. Krokhina. (From *Vestnik Mashinostroyenia*, No. 12, December 1954, pp. 68-70, 2 illustrations.)

Among the shortcomings of electroplated nickel coatings are the impossibility of plating inside cavities and the irregularity of the coating thickness when plating a profiled surface. Moreover, electroplated nickel is soft and hence cannot be applied to surfaces subject to wear. Economic disadvantages are the large investment required for the supply of electric power, the low capacity of the process, which leads to large plating baths occupying considerable factory floor space, the tying up of a large quantity of nickel, and high labour costs.

The chemistry of the reduction of nickel by hypophosphites is insufficiently clarified. According to the data of Brenner and Riddell, two independent reactions take place, i.e., the nickel reduction

$$Ni^{++} + H_2PO_2^- + H_2O \rightarrow Ni + 2H^+ + H_2PO_3^-$$

and the reaction of oxidation of the hypophosphite by water

$$H_2PO_2^- + H_2O \rightarrow H_2 + H_2PO_3^-$$

In another view a single reaction takes place in which the hypophosphite is oxidised to a phosphate. The present authors' investigations have shown that the end product of the reaction is a phosphate and not a phosphite.

It is noted that, in the absence of nickel ions in the solution, the oxidation of the hypophosphite by water can take place on the surface of a metallic catalyst, which may be nickel or iron, accompanied by the formation of hydrogen. The two reactions mentioned earlier are apparently somehow interconnected. It is possible that the initial reaction is the oxidation of the hypophosphite on a catalytic surface when atomic hydrogen is formed. This partly combines into molecules, escapes in gaseous form, and partly reduces the nickel ions to a metallic state. Thus, the following reactions take place:—

$$H_2PO_2^- + H_2O \rightarrow 2H + H_2PO_3^-,$$
$$Ni^{++} + 2H \rightarrow Ni + 2H^+.$$

It has also remained uncertain how the phosphorus, which is found in the nickel deposit to the extent of from 3 to 8%, has been formed.

The following observations determine the technical peculiarities of the process of chemical nickel plating:—

(1) The formation of nickel proceeds at the expense of the nickel salt in solution, the concentration of which falls continuously. Moreover, the hypophosphite is also used up. In addition, hydrogen, acid, and phosphites are also formed. The last two substances accumulate in the solution as the process continues. In this way, the chemical nickel-plating process is characterised by a continuous variation in the composition of the solution.

(2) Since the reduction of nickel takes place on the surface of a plated component, the thickness of the nickel deposit is entirely uniform everywhere on the surface, irrespective of the shape of the component, and including grooves, holes, and cavities. This property of the process permits a reduction in the thickness of a nickel coat compared with the average thickness of an electroplated coat. This reduction may reach 30%.

(3) The hardness of the nickel coat obtained by chemical reduction is considerably greater than that obtained by electroplating and attains 45 Rockwell C. On heating the nickel-plated components to between 250 and 300° C, the hardness of the coat increases to 60 Rockwell C. This property renders the chemical nickel-plating process suitable for obtaining a hard and wear-resistant surface.

With the chemical process, in which plating area attains from 4 to 6 dm^2/litre of solution, the capacity of the bath can be reduced from 30 to 50 times, compared with that required by the conventional electroplating process. Adhesion of chemically plated coats is as good as that of electroplated deposits.

The process in its direct form is especially suitable for iron, German silver, and silver. After a short initial contact with one of the catalytic metals, copper, brass, and tin and phosphor bronzes can also be chemically nickel-plated. However, cadmium, lead, silicon manganese bronze, and lead bronze cannot be chemically nickel-plated at all. Brass containing more than 1·5% lead can be nickel-plated only with difficulty.

As mentioned earlier, the solution for chemical nickel plating contains two basic components, i.e., a nickel salt and a hypophosphite. The following nickel salts can be used:—Nickel sulphate, nickel chloride, and nickel ammonium sulphate. Among the reducing agents, the hypophosphites of potassium, sodium, barium, and calcium are suitable. In addition to the basic components, the solution must contain buffer solutions to prevent a sharp reduction in the pH value of the solution, as a result of acid formation. Among others, sodium acetate and sodium formate can be used as buffer solutions.

The optimum composition of the solution, according to the author's investigations, is given in the following table:—

Component	Concentration, gr/litre		
	I	II	III
Nickel salt:—			
Nickel sulphate	20	—	—
Nickel chloride	—	17	—
Nickel ammonium sulphate	—	—	28
Reducing agent:—			
Calcium hypophosphite	—	16	—
Barium hypophosphite	—	25	—
Sodium hypophosphite	20	20	20
Potassium hypophosphite	20	20	20
Buffer solution:—			
Sodium formate	8	8	8
Sodium acetate	8	8	8

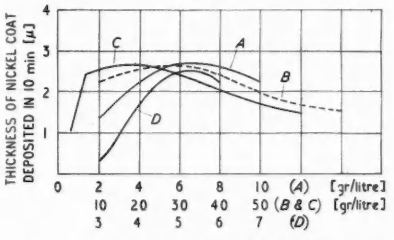


Fig. 1. **Dependence of rate of nickel separation on concentration of :—**
(*A*) $NaCHO_2$. (*C*) Ca $(H_2PO_2)_2$.
(*B*) $NiCl_2.6H_2O$. (*D*) pH value.

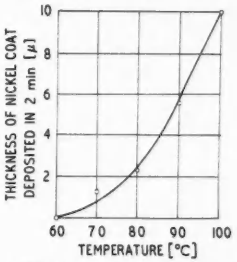


Fig. 2. **Dependence of rate of nickel separation on temperature of solution.**

The temperature of the solution should be between 90 and 92° C, and its pH value between 5·0 and 6·5. The relations between the speed of the process, the concentration of the separate components, and the influence of the conditions of the process are shown in Figs. 1 and 2.

The attempt to conduct chemical nickel plating as a continuous process with measured additions of the salts being used up has proved to be uneconomical, because the phosphites, sulphates, or chlorides accumulating in the solution slow down the process. Moreover, the nickel phosphites, which have a low solubility, form a sediment and spoil the nickel deposit.

Frequent filtration of the solution somewhat reduces this phenomenon, but causes a substantial loss of nickel (exceeding 50%). The process can be conducted for long periods at a load density between 0·1 and 0·3 dm²/litre, but the solution must sometimes be completely renewed.

In view of these observations, it is recommended that the process be conducted intermittently, with full utilisation of the solution in each single cycle, in which case the density of loading can be increased to 4 to 6 dm²/litre. Such a method is economical, because it does not call for frequent filtration of the solution and the considerable loss of nickel associated with it. The rate of deposit formation in this method is greater than that in normal electroplating. The duration of nickel plating and the density of loading possible with full utilisation of the solution can be computed from the following empirical formulae derived from the authors' tests :—

The density of loading is $D = 40/a$ dm²/litre, where a is the thickness of the nickel deposit in microns, and the duration of nickel plating in hours is $t = D/5$.

The preparation of a surface for chemical nickel plating is performed in the same way as for electroplating. Suspension of components in the bath on non-metallic fittings can be employed, as well as loading in baskets or, in the case of small components, these can be placed directly in the bath. After nickel plating the components must, as usual, be washed and dried. When the thickness of the coat is between 10 and 15 microns, the surface of the components is, as a rule, bright and needs almost no polishing.

FRANCE

A "Liquid-Vapour" Automatic Electric Motor Starter

(From *Electro Magazine*, Vol. 6, No. 38, December 1954, pp. 31-33, 9 illustrations.)

This article describes a novel type of starter for wound-rotor induction motors of up to 100 hp, utilising the considerable difference in specific resistance which exists between a liquid and its vapour. The starter is of simple design and very small dimensions, has no moving parts, and controls the starting-up process automatically.

THE apparatus described in this article has been designed for starting up wound-rotor asynchronous motors by inserting into the rotor circuit a star-connected resistance of an automatically variable value. The object is to limit the starting current drawn from the supply mains to a minimum consistent with an adequate starting torque, depending on the operating conditions, and at the same time automatically to control the starting-up process. It is based on the large difference which exists between the specific resistance of a liquid and its vapour, the respective values of which may be in the ratio of 1 to 50.

The apparatus (Fig. 1) essentially consists of two opposing electrodes inside a closed " electrode chamber " of a few cubic centimetres in volume, itself submerged in a much larger volume of liquid (approximately 4 to 5 litres). The electrode chamber is provided with holes through which the liquid can communicate with the interior of the chamber, the rate of flow in either direction being a function of the 4th power of the diameter of the holes. The principal components of the starter are shown in Fig. 2.

The current flows through the liquid from one electrode to the other; however, when its intensity is high, the dissipation of energy is such as to produce an instantaneous evaporation of that part of the liquid which is in contact with the electrodes. The chamber is thus instantly, i.e., in the course of one cycle, filled with vapour, 1 cc of water producing approximately 1240 cc of vapour; as a result, the resistance of the circuit immediately becomes very high. In this process of evaporation there is, however, a critical or threshold value, depending mainly on the current density at the electrode surface; beyond this threshold, the higher the intensity of the current, the more rapid is the evaporation. Thus, if the current flowing through the

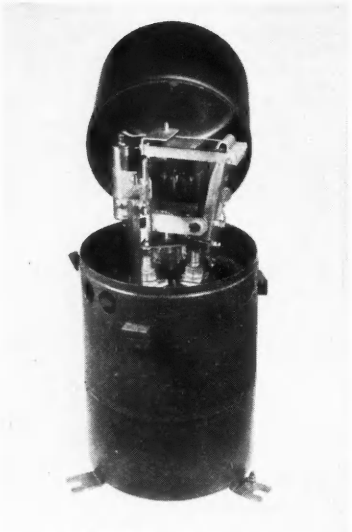
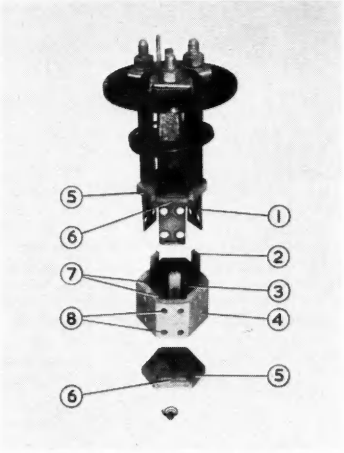


Fig. 1. (left) **General view of starter.**

Fig. 2. (right) **Exploded view of starter, showing principal components.**

(1) Electrodes.
(2) Insulating separators.
(3) Hollow metal prism.
(4) Hollow insulated block.
(5) Insulated cover plate.
(6) Slots.
(7) Electrode chamber.
(8) Calibrated holes.



electrode chamber decreases from a value higher than the critical value to one which is lower, the resistance of the circuit will decrease simultaneously from a very high value (corresponding to the chamber filled entirely with vapour) to a low value (corresponding to the chamber containing liquid only). This change of resistance as a function of current intensity, or what amounts to the same as a function of the voltage applied, is the basic principle of the new starter.

Design and Operation

The current of each rotor phase flows through a small volume of electrolyte between the two opposing electrodes. This volume is determined by the size and spacing of these electrodes, as well as by the thickness of a small plate of insulating material placed between them.

On starting up, the current exceeds in value the threshold limit and thus instantly produces the evaporation of all the liquid in contact with the electrodes; the effect of this is equivalent to the instantaneous connection of a high resistance in series with the rotor circuit and, as a result, the starting current is limited to from 2 to 3 times the nominal current of the motor. As the starting-up process continues, the voltage at the terminals of the starter (and consequently the current flowing through the electrode chamber) decreases; at the same time, the vapour gradually escapes and the liquid re-enters the chamber. The resistance in the rotor circuit, which depends on the proportion of the liquid to vapour in the chamber at any given moment, likewise decreases.

At the end of the starting-up period, the chamber is again filled with liquid; the current flowing through is the rated secondary current of the motor and its value is less than the threshold value of the starter. There is no further evaporation, the residual resistance is low, and the starter may be short-circuited. The behaviour of the resistance during the starting-up period is shown in Fig. 3. It will be seen that it decreases very gradually, whereas the resistance of conventional starters decreases in steps.

However, in the case of prolonged starting-up periods, it may happen that the vapour escapes too rapidly and that the secondary current for a given resistance between the maximum and minimum of the curve is still in excess of the threshold value. In such a case, renewed evaporation takes place before the liquid has again completely filled the chamber, increasing the resistance to a suitable value. A graph illustrating this condition is shown in Fig. 4.

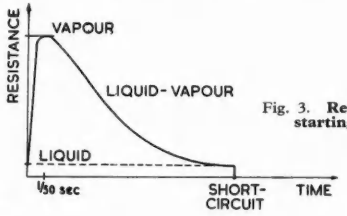


Fig. 3. **Resistance during starting-up period.**

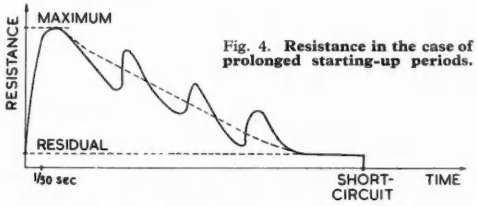


Fig. 4. **Resistance in the case of prolonged starting-up periods.**

The residual resistance of the starter at the end of the starting-up process is that of the electrode chamber filled entirely with liquid, and corresponds to a rotor slip of approximately 12%. This resistance depends on the surface areas of the electrodes facing the insulating plate, and is eventually eliminated by a short-circuiting time switch incorporated in the starter.

Technical Advantages

It has been shown that the resistance inserted into the secondary winding is a direct function of the power taken by the motor from the mains, as the rate of evaporation depends on this value. This condition produces a self-regulating effect, in which the motor may be said to act as a servo-motor controlling the total resistance of the rotor circuit. This resistance will therefore automatically and instantly respond to any operating conditions that may occur.

A further advantage of the starter is its wide range of resistance. Thus, it is able to cope adequately with any starting-up conditions and to select automatically the optimum resistance values at any time. Furthermore, the same starter can be used for motors of different types

(*Concluded on page* 123)

Thread Peeling of Leadscrews

By W. STENDER. (From *Werkstattstechnik und Maschinenbau*, Vol. 44, No. 11, November 1954, pp. 531-538, 18 illustrations.)

Commonly used machining processes in the production of accurate leadscrews compare unfavourably with other modern machining processes, and the accepted view is that the required quality cannot be reconciled with short production times. The following paper presents the results of lengthy development work which has culminated in the introduction of a rapid thread-peeling process, and may be said to provide a new solution for an old problem.

To achieve the results required for thread peeling of leadscrews, high cutting speeds, carbide-tipped tools rotating uniformly and without vibration, and rigid, specially built machines must obviously be employed. It is also clear that high rotational speeds cannot be applied to long leadscrews. Conventional milling cutters cannot be considered because of the harmful effect of multiple cutting edges on surface finish and because of the practical limitations to maximum inertia of the milling spindle. The planetary-cutter system, as used in the U.S.A. for some considerable time in fine-thread production, and as developed in Germany during the last war, appears, however, to be a process most suitable for thread production.

In this process, the cutting edges are inclined towards the centre of rotation and rotate along a circular path. The relative eccentricity of this circle in relation to the component causes the cutting edges to enter the work from one side. This is illustrated and compared with thread milling in Fig. 1. The same feed angle ω is used in Figs. 1a and 1b, and it can be seen that, provided r, r_k, and ω are constant, the "peeled" and milled chips must be of equal cross-sectional area. The peeled chip, however, is longer and narrower and therefore requires a lower cutting force of a longer duration. In practice, assuming a constant angle ω, the ratio of chip thicknesses in the two processes is 3 to 1. Conversely, the feed angle can be trebled when peeling, using the same cutting force.

In contrast with turning, the thread profile produced by milling or peeling is not strictly circular, and is, in fact, virtually polygonal. In practice, however, the height of these deviations from a true circle is measurable only in thousandths of a millimetre and there is as yet no evidence of any harmful effects from them. They may even be helpful, if they act as minute lubricant pockets. The actual height of the peaks is:—

$$y = \frac{d_k\,\omega}{4}\left(1 \pm \frac{d_k}{D}\right)$$

ω being expressed in radians and the other values being in mm. The positive sign applies to milling and the negative sign to peeling; generally, d_k is somewhat smaller than D.

Fig. 2 shows the effect of normal diameter ratios on the magnitude of y, with constant values of d_k and ω. If ω remains constant, the value of y is much smaller for peeling than for milling; alternatively, ω can be greatly increased for a given value of y. If, for purposes of comparison, the value of the function in brackets is taken as 0·2 for peeling and 1·8 for milling, it is found that ω^2 can be increased 9 times, or the value of ω can be trebled before the same peak height is reached by peeling. Although these considerations apply to the minor thread diameter only, similar values will also apply to the thread flanks, if measured radially. The unevenness of the flanks is nevertheless reduced by the size of the flank angle, and, using angles common for Acme-type threads, this means that the inaccuracy is reduced to about one quarter.

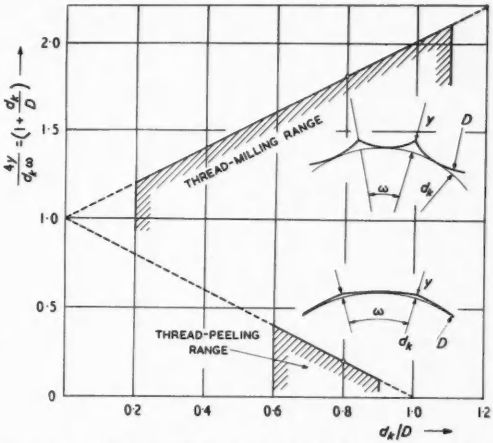


Fig. 2. **Magnitude of flank undulations for thread peeling and thread milling.**

In addition to the magnitude, the profile of the undulations must also be considered. The portion between two peaks is hollow in milling but, when peeling,

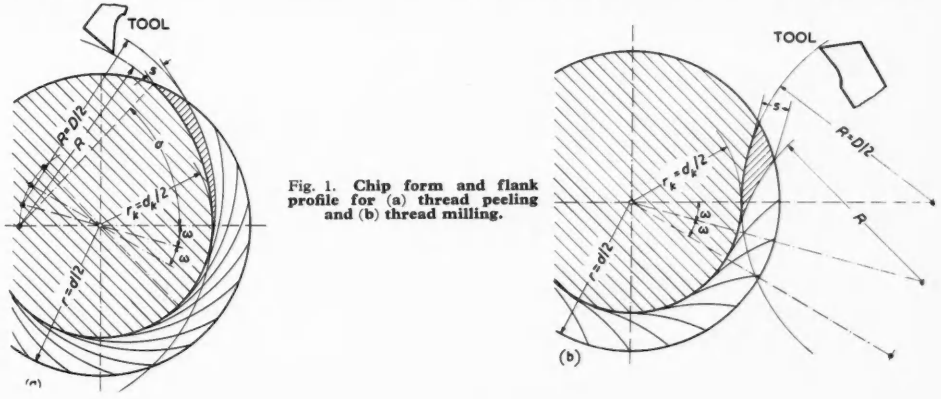


Fig. 1. **Chip form and flank profile for (a) thread peeling and (b) thread milling.**

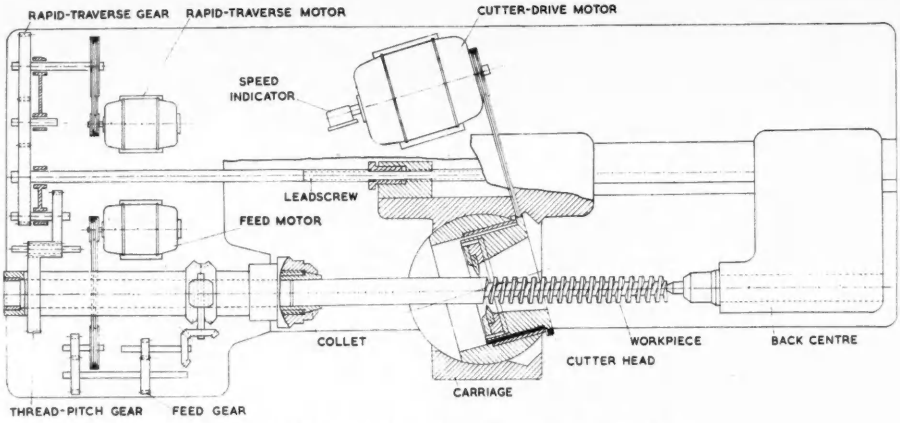


Fig. 3. **Driving arrangements of thread-peeling machine.**

it becomes convex and approaches a circle; as such, it is more acceptable.

The thread-Peeling machine

Fig. 3 shows schematically the driving arrangements of the machine. The saddle and back centre are carried on an exceptionally rigid base, and the vertical slideways are situated at the back of the machine, to avoid risk of damage from the small and sharp chips. The ways are also protected by covers. Fallen swarf is collected in a container under the machine and can be removed from the rear.

The planetary tool mechanism, together with its driving motor, is mounted on a heavily constructed carriage. The component is held in a chuck attached to a hollow spindle and is supported by a back centre. The ratio between speed and carriage feed corresponding to any given thread pitch is provided by gearing interposed between the spindle and leadscrew. The direction of saddle movement during operation is from back centre towards the chuck. The plane of tool rotation can be adjusted to suit the pitch angle. As shown in Fig. 1, the cut starts at the wide end of the chip, so that the operation must necessarily be unidirectional, as in climb milling, and this condition automatically determines the direction of rotation of the tools. The feed motor which the spindle and the leadscrew is in the main gear-box.

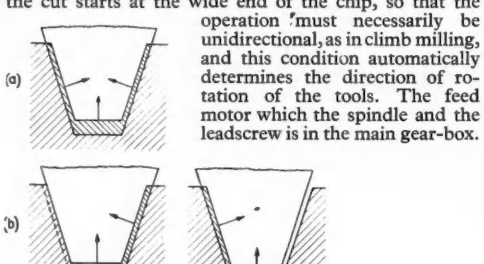


Fig. 4. **Chip sections resulting from various tooling methods.**
(a) One-tool method. Thick root chip, pressure from both sides, chip flow very restricted.
(b) Two-tool method. Pressure from one side, unbalanced axial pressure, partially restricted chip flow.
(c) Three-tool method. All the above disadvantages eliminated.

A separate motor is used for rapid traverse. All change-gears are easily accessible under a hinged cover on the main gearbox. The special collet-type chucks mounted on the heavy, hollow, plain bearing spindle are designed for extremely accurate centering.

The actual cutting mechanism runs in an oil-mist-lubricated, double-row ball bearing and this is mounted in a strong cylindrical casting with a vertical column; the entire housing can be swivelled by hand to suit the pitch angle by means of a worm gear. The eccentricity of the circular tool path is set by adjusting the column from its vertical position by means of another handwheel and the tools are in this way set to cut from below, the depth of cut being shown on a dial indicator. The cutter-head drive motor, with steplessly variable speed, drives through V-belts and is located on top of the carriage column. Support arms, located at both sides of the carriage, act as steadies, and are set to the work diameter by screws provided with measuring scales. These arms can be moved into position or withdrawn by compressed air. Similar steadies also act from above.

The control panel is located on the carriage side. Automatic safety switches, which ensure that the carriage cannot run into either the headstock or back centre, and also prevent a change to rapid traverse if the tools are engaged, are provided.

Tooling

The most frequently used thread form for leadscrews is trapezoidal. The system selected uses three tools, and no two surfaces with a common corner can be machined in one cut; furthermore, there are no unbalanced axial forces, and the ratio between chip thickness on the flanks and the thread root does not exceed 1:2. The tool

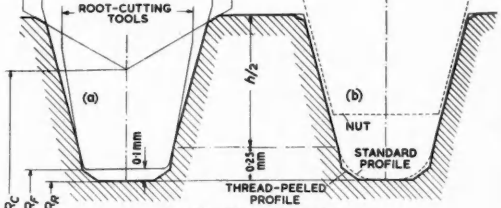


Fig. 5. **Thread Profile**
(a) Profile development with various peeling tools.
(b) Deviations of thread-peeled profile from standard.

sequence comprises the tool for machining the root, the double-sided tool for the flanks, and the tool for finishing the root. Different tool systems, with one, two, and three cutters, are shown diagramatically in Fig. 4. The finished thread profile is shown in Fig. 5, in which a slight discrepancy from the standard profile will be seen at the root; this is required to assist machining, but the load-carrying flanks are unaffected. A chamfering tool is provided to break the corners to permit the use of steadies. Consequently, a four-tool head is required, incorporating two diametrically opposed thread-root tools, and the flank and chamfering tools. This simple cutter head merely requires precision adjustment on the thread-root tools. The flank profile is unaffected by slight setting inaccuracies or by tool eccentricity. An almost tangential setting of the tools was found to be most suitable. The V-section tools are located in accurately machined grooves, supported against axial pressure, and held by retaining clamps. This simple arrangement also assists in easy and rapid tool replacement. The tool-holders themselves are adjustable in slots machined in the baseplate of the cutter head. The tools are set accurately to the required radii with a special gauge and are then clamped; the cutting diameter must inevitably be larger than the work diameter, to allow for the eccentric operation. The difference in the two diameters should, however, be kept to a minimum, to give the best possible cutting conditions and to assist smooth cutting.

It is obvious that these tools, which are set at 15 deg. to the tangent, are better able to withstand the cutting loads than radially set tools, which are subject to bending stresses. Moreover, the carbide tip can be from 15 to 20 mm in length in the axial direction, without being endangered by bending loads. Tool regrinding is simple and entails only surface grinding of the 15-deg. inclined face and the lapping of narrow lands on both the root and the flank cutting edges.

The setting angle of 15 deg. automatically provides an identical clearance angle. The clearance on the side cutting edges is also influenced by the flank angle and pitch angle of the thread produced. The clearance angle on the flank α is about 4 deg. for a 30-deg. trapezoidal thread with a small pitch; at the worst, it can be 3·7 deg., assuming a 29-deg. trapezoidal thread (Acme type) with a maximum pitch angle of about 15 deg. It can be seen from these values that the angles are rather smaller than is desirable.

The clearance angles of the flank cutting edges are further reduced and complicated on coarse- and large-pitch threads, owing to the pitch-angle variation between the crest and root. This is particularly critical on deep threads and on multi-start threads. For example, threads with more than three starts cannot be produced on the thread-peeling machine at all; the same applies to square threads.

Work Holding and Steadying

The work is held on the left side in a collet chuck in the machine spindle, but can also be extended through or even beyond the hollow spindle and can be clamped by exchangeable collets. The accurate centering of the work in the collets is most important in avoiding thread run-out. Exceptionally long components can be supported by a guide bush at the left-hand end of the hollow spindle, to avoid bending or sagging.

The right-hand end of the component is supported by the back centre, using either a carbide centre or a guide bush. The latter is particularly useful for long components, which can project through the bush. Exceptionally long components must also be supported by an additional steady. The spring pressure of the back centre allows free expansion of the component, caused by heating up during cutting or by released internal stresses, and a dial gauge is provided to measure this movement.

The steadies, which are located as close as possible to the cutter head, obviate bending of the component, ensure an accurate and constant depth of cut, and prevent distortion due to cutting pressure. Both steadies are constantly in use, except when the cutter is in close proximity to the chuck or steady; this, however, is unimportant, as there is adequate support at these points. Some vibration may occur with exceptionally slender components, despite the ample steady support; in such cases special simple vibration dampers are used and these are most effective. The upper steady is provided with a flat plastic shoe which is brought into contact with the component and then clamped in position. In cases where the component is relatively inaccurate, or where there is danger of vibration, the shoe can be left unclamped and is then held against the component by compressed air. The design of the hollow spindle, back centre, and steadies is such that it allows leadscrews of a length exceeding the nominal distance between centres to be machined in two stages. This procedure produces results without pitch error; its principle is illustrated in Fig. 6. The component is held by the steadies in a constant position to the cutter head, and cutting therefore proceeds from exactly the same point where it finished before the component was moved.

Accuracy

Mechanical shortcomings, such as misalignment, play, and pitch inaccuracy, were counteracted with great care, and the effect of the remaining errors was carefully examined. The normal tool-profile errors were about $\pm$ 0·003 mm in width and $\pm$ 0·5 minutes in flank inclination. The deviation of the paths of the individual tools was a maximum of 0·01 mm. The effect of such small values on the thread itself is almost negligible.

Leadscrew blanks of medium size are generally ground to a consistent tolerance of $\pm$ 0·01 mm, and this accuracy is adequate for the avoidance of serious errors. The thread diameters, in normal operation, are kept within $\pm$ 0·02 mm.

Pitch errors can be due to: (a) Inaccuracy of machine leadscrew; (b) temperature effects, and (c) locked-up stresses in components.

With respect to (a), it can be said that the leadscrews can never be perfect, but with the aid of various corrective measures and special leadscrew heat treatment, good accuracy, satisfactory for all practical purposes, can be achieved.

To overcome temperature effects, when exceptionally high accuracy is required, it is necessary to locate the

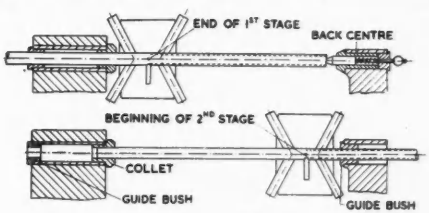


Fig. 6. **Schematic illustration of machining in stages.**

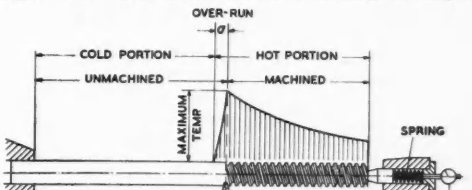


Fig. 7. **Temperature distribution during thread peeling.**

thread-peeling machine in a temperature-controlled room, or at least in a part of the workshop which is not subject to wide temperature variations. It cannot be assumed that the machine and component will follow variations in ambient temperature equally. The component generally heats up faster than the machine leadscrew. A difference of 3° C can cause an error of 0·01 mm in 300 mm length, and this alone accounts for the major part of the permissible error. Even the heat from operators' hands or the effect of cold floors must be taken into account. The temperature distribution in thread peeling is illustrated in Fig. 7. Heat is developed at the cutting point and this is increased by the temperature of the component. The already-machined portion of the component gradually cools off, so that a temperature gradient exists, but the temperature level is still too high. This section can expand freely to the right. The left-hand section, however, remains cool and there is no change in work length to the cutting point. Nevertheless, there is a short distance a on the unmachined side which is warm, and its length depends on the peak temperature at the cutting point and on the rate of movement of this point. Theoretical considerations show that the maximum length can be only a few centimetres and that this factor does not affect pitch accuracy to any noticeable extent. In practice, during cutting, no heating-up is noticeable in front of the cutting point, whereas a temperature rise of 10 to 20° C can easily be detected behind this point. The feed, in fact, keeps abreast of the heating up, and in some cases may actually overtake it. In addition, there is the cooling effect of the compressed-air stream which is directed at the cutting point to prevent swarf accumulation.

A different problem arises when the thread is produced in several passes, or with multi-start threads. In such cases it is essential to reproduce the starting temperature before the finishing cut is taken.

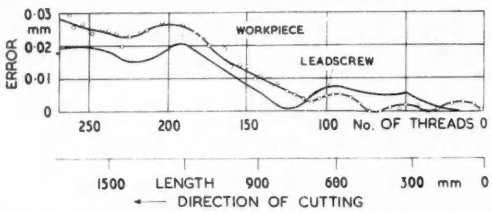


Fig. 8. **Example of pitch error in a thread-peeled spindle compared with the leadscrew.**

With regard to locked-up stresses, these are mainly caused during rolling of the bar material. The core of the bar contracts if the outer layers are cut, as is the case in thread cutting. This difficulty is met by roughing out the thread with a narrow tool with the finished depth, but with a reduced width. Both thread flanks are left with a finishing allowance corresponding to the expected distortion plus a certain additional allowance. This permits the screw to distort, and when the finishing cut is then taken with the final tool, after adequate cooling down, no further noticeable pitch change takes place.

The majority of leadscrews can be produced in one cut, partly owing to the fact that the materials used are more or less dimensionally stable; the resulting errors are generally negligible. Multi-start threads are more susceptible to inaccuracy in this respect because, in addition to the risk of pitch inaccuracy, there is a danger of relative lead inaccuracy. Roughing and finishing is highly advisable in these cases.

Fig. 11 shows the results of pitch accuracy produced without prior roughing. Ambient temperatures were very unfavourable. Assuming a perfect leadscrew—the actual leadscrew used had above-average errors—a pitch error of less than 0·01 mm in the total length of 1·7 m would be produced; the pitch error in the most unfavourable section of 0·9 m length would be 0·013 mm.

Cutting Performance

From past experience with carbide tools it seems advisable to use cutting speeds between 100 and 150 m/min. Cutting-speed tests, in which the criterion for the lower speed limit was the production of a matte surface, showed that a suitable speed for steels with a tensile strength between 90 and 100 kg/mm² was about 100 m/min, whereas the equivalent value for steels of about 60 to 70 kg/mm² was in the region of 125 m/min. Speeds over 150 m/min are uneconomical, since they result in shorter tool life, as has been proved on many occasions.

The upper and lower chip-thickness limit also had to be determined. Basically, it was found that the average chip thickness must be taken as the chip volume divided by the plan area of the chip. This average chip thickness is used in all considerations in connection with thread peeling, because the flank chip has no obvious dimension which can be related to the average chip thickness.

It would have been preferable to utilise in all cases the maximum permissible chip thickness. There are, however, several limitations which cannot all be predetermined mathematically. The factors which must be considered are the limited force and inertia of the cutter drive, the strength of the tools and their mounting, the rigidity of work holding, and general requirements for quiet machine operation. Flank unevenness is especially important. Bearing in mind the above limitations (the mounting and clamping of tools did not appear to be limiting factors), average chip thicknesses of 0·12 to 0·15 mm were found suitable. The actual thread-peeling time depends on chip thickness because of the relationships between chip thickness and work speed n_w (which determine the feed) and between n_w and the feed rate of the cutter-head carriage.

The rotational speed of the workpiece is:—

$$n_w = \frac{202{\cdot}6\ \sigma\ (v/d)}{\tau - 1 + \frac{d}{2s}(2\tau - \tau^2)} \quad \text{[radians/min]}$$

$$\cos\sigma = \tfrac{1}{2}\left(1 - \frac{1-\tau}{f} + \frac{f-(1/f)}{f-1+\tau}\right),$$

where

σ = angle of cutting circle, corresponding to the cutting length [radians],
v = cutting speed [m/min],
d = component diameter [mm],
τ = ratio of thread depth to outside diameter,
s = chip thickness [mm], and
f = ratio of cutting-circle diameter D to component diameter d.

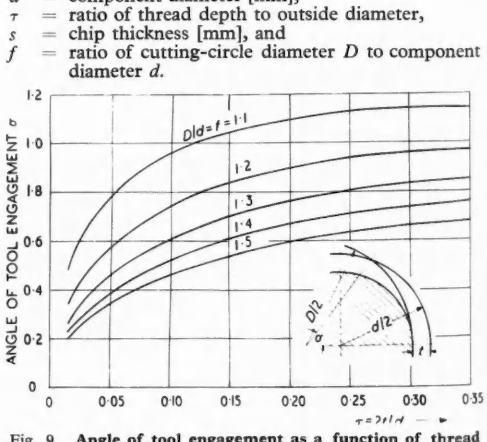


Fig. 9. **Angle of tool engagement as a function of thread depth and diameter ratio.**

The value of σ as a function of τ, for various values of f, is determined from Fig. 9. The diameter ratio f is generally taken to be about 1·1. Only unusually large pitches and thread depths require higher values of f, to avoid undercutting on the flanks.

The following simple and approximate empirical formula was developed for determining n_w, in which f is assumed to be 1·1 :—

$$n_w = \frac{373\, v\, s}{d^2\, \tau^{0\cdot75}} \quad \text{[radians/min]}$$

For f-values of 1·2, 1·3, 1·4, and 1·5, a reduction of 20, 30, 40, and 50% respectively must be allowed.

The machining time for a 1-metre length of component is obtained from :—

$$T_1 = \frac{1000}{h\, n_w} \quad \text{[min/m]},$$

where h = pitch.

No modification of the above is necessary for multi-start threads, as each pass requires a time equal to the total time T_1 divided by the number of starts. Multi-start threads do, however, involve higher auxiliary times.

The rotational speed of the work and the machining time are determined, using the given work diameter, pitch, normal surface cutting speed for the particular material in hand, and a selected chip thickness. The times which are obtained in this way may appear to be unexpectedly short, but they do correspond closely to present every-day practice. All machining or thread-peeling times lie within 0·2d and 0·9d min/m.

Tool Wear and Tool Life

The only result of tool wear is a steady increase effective thread diameter and, as the wear is linear, its effect can be counteracted. On short components, half the expected error can be allowed for from the start, and on longer components the correction must be carried out in stages.

The diameter increase to be expected is found after a short observation, and the cutting-depth setting has to be adjusted accordingly at given intervals. This correction can be carried out very accurately with the aid of a setting device of the dial-gauge type. The diameter variation in leadscrews of from 3 to 4 m in length and of 50 to 60 mm in diameter need be no more than 0·015 to 0·025 mm. Without these measures, the diameter increase would be of the order of 0·1 mm or more. In quantity production it is usual to use the value of the error found on one completed component as the correction allowance for the next component. The tangential tools have the advantage that no change in profile takes place during regrinding; this considerably simplifies regrinding and subsequent inspection. The wear marks on the clearance face must be completely removed during regrinding. Insufficient clearance angles result in high tool consumption, but have no effect on tool life. A thread-peeling tool can be reground about 20 to 30 times on each end before it needs replacement.

The criterion of economy of a process of this type is the length of component produced between regrinds, rather than the time between regrinds. The factors influencing this value, other than the quality and shape of the tool, are work material, cutting conditions, and, of course, the geometrical form of the thread.

It is well known that heat treatment of a material can affect its machinability, without changing its tensile strength. Alloying elements also influence machinability, chromium in particular having a very detrimental affect. The influence of alloying elements may explain the different machinability of steels whose carbon content and hardness may be quite similar. Medium steels with a tensile strength of between 55 and 75 kg/mm² appear to be most suitable in that they result in the smallest tool wear; nevertheless, small differences of various kinds can affect their machinability very considerably.

The width of the chip, as given by the depth of thread, assuming a constant chip thickness, may have little influence on the cutting distance between regrinds. An increase in chip thickness, however, results in higher cutting resistance and heat evolution, and it can be assumed that this will affect tool wear. On the other hand, it was found that wear takes place only on the clearance face. It can therefore be assumed that the total length of contact between tool and work is of greater importance than the chip thickness. Provided that there are no relevant test data available, either the length of contact or a combination of length of contact and chip thickness may be regarded as the factor governing tool wear. Mathematical considerations should not be accepted blindly, because there are as yet insufficiently reliable data available. Practical experience seems to indicate that the chip thickness, within reasonable limits, exerts little influence on the length of thread produced between regrinds. Assuming this to be correct, the following approximate empirical formula can be recommended :—

$$L = \frac{K}{d\, \tau^{0\cdot125}} = \frac{K}{d}\left(\frac{d}{h + 0\cdot5}\right)^{0\cdot125} \quad \text{[m]},$$

where d and h are in mm, and K = 250 to 300 for " difficult " steels, 300 to 450 for medium steels, and 450 to 650 for very easily machinable materials.

In view of the approximate nature of the above formula, it is sufficiently accurate to take $\tau^{0\cdot125} = 0\cdot8$.

The above remarks apply to the life of the flank-cutting tools; the root-cutting tools have a considerably longer life, but generally both tools are replaced at the same time for economical reasons. The chamfering tool, however, can be used very much longer before regrinding becomes necessary.

Production Time

The auxiliary times are of great importance, in view of the very short machining time. In thread peeling auxiliary times include setting up, tool changing, work loading and unloading, reclamping of components whose length exceeds the distance between centres, and, in exceptional cases, time allowed for cooling the work.

Setting-up includes precise adjustments, which must be carried out thoroughly if accurate results are to be achieved. About 40 min must be allowed for adjusting and inspecting the cutting circle of the tools, height of the steadies, and the effective thread diameter, and a further 25 min is required for other adjustments. These values apply to the first component of a batch and to a moderately skilled operator.

Unloading one component and loading the next one of a batch normally requires 8 to 10 min, except in the case of very long or heavy components which cannot be handled by one operator. Reversing or changing tools requires some 15 to 18 min, and it has been found that this can be carried out at any time during the cutting operation, without affecting the thread-pitch accuracy. The unmachined part of the component must, however, be cooled by compressed air during the tool-change period, to prevent heat flow from the machined portion.

If the cutting conditions are as efficient as possible consistent with the required accuracy, it is generally possible to work continuously, i.e., without any idle time. Intelligent planning of the sequence of operations and batching can greatly reduce auxiliary times; the cooling periods needed when roughing, or when machining multi-start threads, can be fully or at least partially utilised by removing partly machined components and carrying on with the same operation on the next component. The part-machined component is replaced after cooling off, and its accurate location in its original position is ensured by means of a special measuring or setting device.

GERMANY

Two-Stroke Diesel Engine without Crankshaft

By M. R. G. TEISEN. (From *Motortechnische Zeitschrift* (*M.T.Z.*), Vol. 15, No. 12, December 1954, pp. 362-363, 5 illustrations.)

A NEW type of opposed-piston two-stroke diesel engine without crankshaft, designed primarily for trawlers, tugs, and launches, has been developed by Svanemölle Company, of Copenhagen. It is a small and compact engine, capable of rapid acceleration, while retaining the features of a slow-running, heavy-duty, direct-coupled marine propulsion unit.

For economy and reliability, uniflow scavenging was adopted. The piston forces are transmitted by rocker arms, in the same way as in previous designs of Junkers and Sulzer, so that the side thrust of the piston is extremely low.

Previous double-piston designs had normal crankshafts with two throws per cylinder, but these, in multi-cylinder engines, gave rise to serious torsional vibration problems. These problems have been avoided in the new design. The method of power transmission from the piston *via* a rocker arm to the cam on the main rotor shaft eliminates vibration and also permits a reduction in the piston speed. On the basis of tests conducted by Professor Niemann, which clarified the problem of permissible loads between rollers and cams, it was decided to employ an arrangement such as that shown in Figs. 1 and 2.

The engine illustrated is a three-cylinder, double-piston design, with a bore of 150 mm and 2 × 150 mm stroke. The rotor shaft, provided with cams, is supported in roller bearings and runs at 350 rpm, corresponding to twice as many working cycles per minute for each cylinder. The engine develops 150 bhp at a mean effective pressure of 87 psi. The cams, made of ball-bearing steel and hardened to 63 Rockwell-C, are mounted together with cylindrical intermediate sections on a plain rotor shaft which carries a flywheel at its flanged end on the right-hand side. Each line of cylinders (left and right) is cast integrally in one block and bolted to cast-steel cross webs; these transmit the pull of the rocker-arm bearings in such a way that the grey-cast-iron parts are not subjected to tensile loads. The cylinder block, the cast-steel cross-webs, and a set of cams and rocker arms thus form a sub-assembly, and make possible the construction of a range of engines with 2, 3, 4, 5, and 6 cylinders, all of which can have the same auxiliaries, controls, etc.

A transverse section through the auxiliary drives is shown in Fig. 2. The lubricating-oil vane-type pump is also designed as a servo-motor for the control of variable-pitch propellers. The piston-type water pump, driven through a worm gear (on the right), serves as a bilge pump on the lower side and as a cooling-water pump on the upper side of the double-acting piston. The same pumps are employed on all engines; their delivery can be adapted to the number of cylinders by using a worm drive with a number of starts equal to the number of cylinders.

The engine has also been developed for stationary applications. The main components are the same as for the marine engine, but all the auxiliary drives for the stationary version are arranged on the front side. The first test-engine was designed without a scavenge blower, with the personal co-operation of Kadenacy. However, the Kadenacy effect did not give the desired result, possibly owing to the slow running speed, and it was therefore considered necessary to provide a scavenge-air blower, which operates at a pressure of 1·4 psi.

For fuel-consumption measurements, the second and

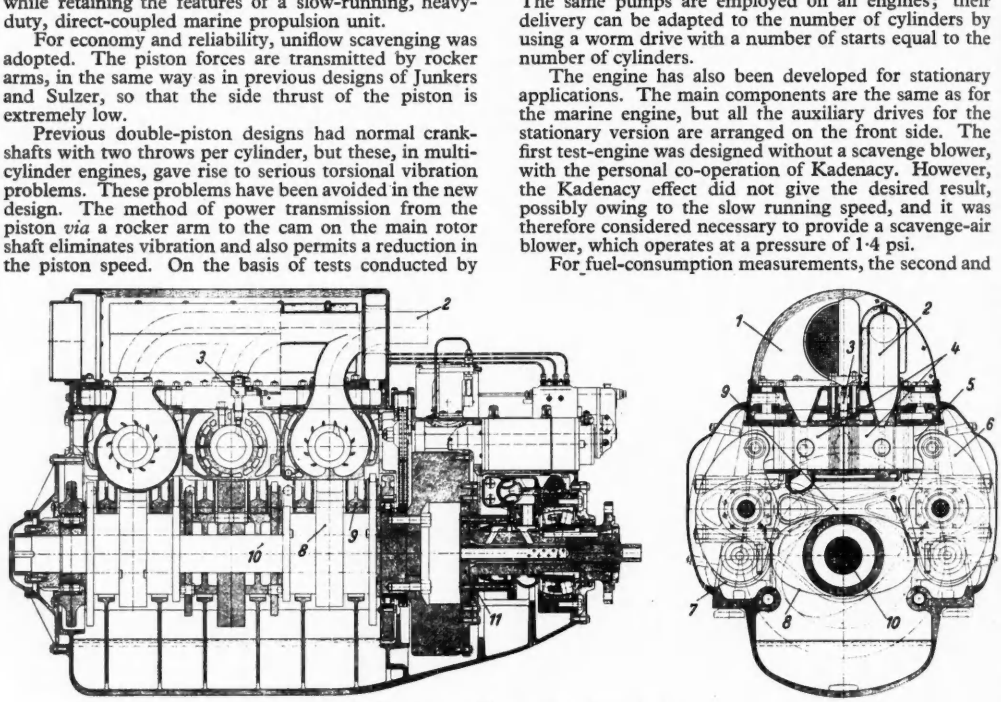


Fig. 1. **The Svanemölle opposed-piston engine.**
(1) Air chest; (2) exhaust; (3) injection nozzle; (4) piston; (5) piston rod; (6) rocker arm; (7) rocker-arm roller; (8) cams; (9) cross webs; (10) central shaft of rotor; (11) oil-pressure piston for adjustment of variable-pitch propeller.

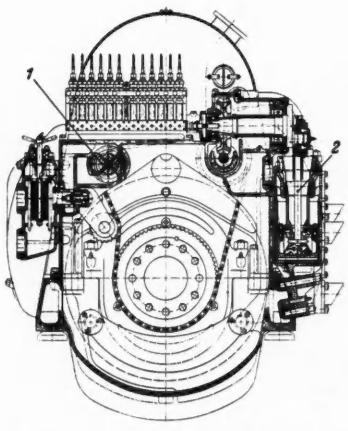


Fig. 2. **Section through auxiliary drives.**
(1) Oil pump; (2) double-acting water pump.

third cylinder, with their operating components, were removed from the test engine, and scavenge air was supplied from an externally driven blower. The tests of the single cylinder showed an optimum consumption of 0·338 lb/bhp-hr, so that the engine, as regards economy, is fully comparable with other designs.

One of the main problems with this design was to keep the wear of rollers and cams as low as possible. This was achieved by the addition of auxiliary cams mounted on the rotor shaft next to the main cam discs, the auxiliary cams being acted upon by the rollers of auxiliary rocker arms, as shown in Fig. 3.

The auxiliary arm with its roller oscillates about the same axis as the main rocker arm. The phasing and contour of the auxiliary cam enables the auxiliary arm to follow exactly the movement of the main lever. The relative rotary movement is taken up by a claw-type clutch, with a play corresponding to a travel of 0·02 in. on the main roller. The clutch operates only in an emergency, e.g., piston seizure. The auxiliary arm is coupled to the main arm by means of a torsion spring, so that the rollers are pressed against the eccentrics with a preload of about 1750 lb.

The 150-hp three-cylinder engine has run for about 3,000 hours on the test-bed, and a similar four-cylinder engine developing 200 hp has been running for one year in an electric power station. In both cases, neither the cams nor the rollers have shown any signs of wear. The specific weight of the engine is approximately 55 lb/hp.

Further development of the engine is in progress, and the basic design is considered suitable also for larger units.

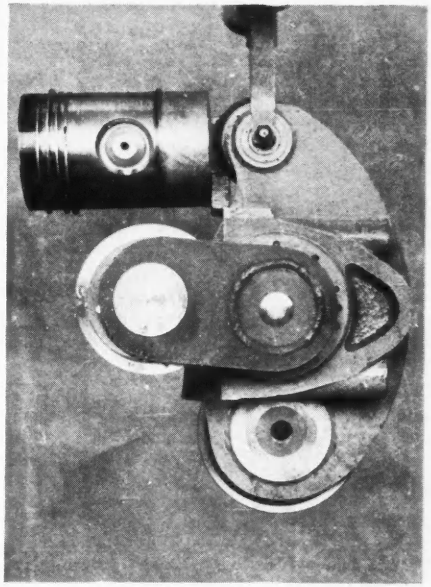


Fig. 3. **Piston and rocker arm.**

U. S. A.

A Survey of Problems of the Thermal Barrier

(From *Mechanical Engineering*, Vol. 76, No. 12, December 1954, pp. 966-977, 21 illustrations.)

In the first instalment of this survey, published last month, overall problems of the thermal barrier in connection with piloted and pilotless aircraft were considered, together with problems of the effects on turbojets and propulsion installation systems. This concluding instalment discusses other effects on systems and on airframes, including stuctural, minimum-weight, and design problems.

(2) EFFECTS ON SYSTEMS (*continued*).

(c) Cooling Systems[5]

Cooling of crew compartments and electronic equipment becomes more important and, at the same time, more difficult as speeds increase. A sharp increase in capacity required from the cooling system takes place when the surrounding air becomes too hot to be a convenient direct heat sink. Heat sinks which can be found in the aircraft are structure and fuel. The structure itself can be used satisfactorily for a short duration, where its thermal lag and capacity are sufficient and where cooling off follows a brief period of excessive temperature. For any flight longer than a few seconds, the whole structure will reach too high a temperature to be useful. Fuel is an attractive heat sink and it can be used conveniently if a heat exchanger between the fuel and the air is used downstream of the fuel pump. Unfortunately, the claim for fuel as a heat sink is made by the engine manufacturer for oil cooling and, so far, the air-conditioning engineer has not been able to obtain fuel for his purposes.

Artificial heat sinks:—As there seem to be no other heat sinks present in the aircraft, it is necessary to create an artificial one, which should be able to absorb heat at the proper temperature level, and the highest possible amount of heat at the smallest possible weight and volume penalty, and which should be easily available and should have no poisonous or highly corrosive properties.

It seems that water is superior to other substances on the basis of heat-absorption capacity, availability, and chemical properties. The superiority of water is so great in these respects that the use of other materials with lower boiling-point temperatures at altitude is rarely justified in aircraft applications.

A typical simple air-cycle system employing a water evaporator is shown in Fig. 4. This type of system is installed in the X-3 high-speed research aircraft. As can be seen from the lines of cooling-air temperature and boiling-water temperature, the system can operate

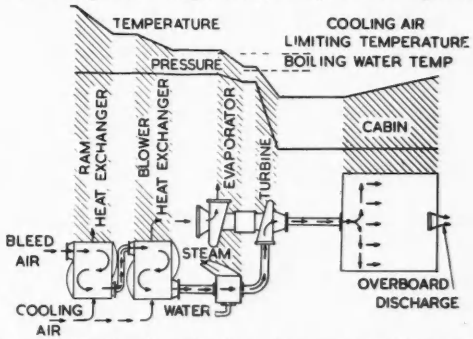


Fig. 4. **Simple air-cycle air-cooling system with water evaporator.**

with the turbine-inlet temperature considerably below cooling-air temperature.

Cooling of supersonic aircraft is so important in terms of its performance that the optimum system can be achieved only through the co-operative efforts of airframe and equipment designers, starting with the preliminary design stage and continuing through the final acceptance of the aircraft.

(D) Human Problems[6]

Altitudes so high that human life is no longer possible without artificial aids may now be reached within a few minutes, and the full range of tolerable temperatures are met within a single flight. Extremes in accelerative forces leading to loss of consciousness or to death may be encountered during manoeuvres.

One of the most important ways of improving flight safety and combat efficiency is to design equipment in terms of human capabilities and limitations. Aeronautical engineers should have an understanding of the sense organs and the characteristics of human perception, if satisfactory information is to be supplied to the pilot. The environmental conditions relating to temperature, humidity, toxic gases, and many other factors must be considered, or physiological limits may be exceeded. Thus, there is great need for more effective collaboration between the engineering and biological sciences.

Lack of oxygen at high altitudes gives rise to a progressive and insidious deterioration of performance. Although cabin-pressurisation and pressure-breathing equipment provide satisfactory solutions, much remains to be done in improving the comfort and reliability of such advances. Sudden loss of pressure is serious, especially the symptoms related to aero-embolism which may occur during explosive decompression. The visual problems encountered at very high altitudes have introduced a number of unusual factors which are being brought under control by redesign of cockpit-illumination systems and other aids to the pilot.

The adverse stimuli relating to high-speed flight centre around the accelerative forces which build up rapidly during sudden manoeuvres, especially during combat flying. Some protection can be afforded pilots by anti-gravity suits, but the limiting factors remain serious, and all pilots should be indoctrinated with regard to their physical responses from such manoeuvres. The visual and motor reaction times of pilots impose serious limitations in high-speed aircraft. The most satisfactory methods of designing the controls of modern aircraft, to come within the range of human capabilities, is deserving of further research.

(3) EFFECTS ON AIRFRAMES

(A) Structural Problems[7]

Thermal stresses:—The wing of a supersonic aircraft is heated only over its surface and its interior remains comparatively cool. Under these conditions the expansion of the material of the hot surface tends to force an expansion of the cooler interior, which opposes such action. The resulting thermal stresses are compressive in the warm outer regions and tensile in the cool interior.

As a comparatively simple example, heating was assumed to be caused by a uniform speed of Mach 3·1 at an altitude of 50,000 ft, with a uniform initial temperature of 60° F. The wing structure was assumed to consist of two steel cover plates, $\frac{3}{8}$-in. in thickness, connected by a number of 0·1-in.-thick steel shear webs.

After 200 sec flight the cover plates reached 540° F, while the middle of the web was at only 110° F. At that time the maximum stress in the structure was the longitudinal tensile stress in the web, midway between the flanges, calculated to be more than 70,000 psi.

When tensile stresses of this order of magnitude actually appear in the comparatively cool portions of the structure, the danger of fracture is evident. On the other hand, extreme thermal stresses in hot regions cannot be maintained for any length of time, because plastic and viscous deformations take place, and these immediately reduce the thermal stresses. It seems advisable, therefore, to provide possibilities for the structure of supersonic aircraft to deform permanently and thereby to escape thermal stresses within limits where safe operation is still possible.

Thermal buckling:—As a slender column is heated, its length would increase if the distance between its end points were not fixed, for example, by a rigid testing machine. The shortening due to the compression must balance the extension caused by heating and therefore the compressive force can be calculated. The highest thermal stresses are likely to occur with a material for which the product of Young's modulus and the coefficient of thermal expansion is the greatest.

The column will remain straight until the force becomes equal to the Euler buckling load; beyond this load bowing occurs. In a numerical example for the buckling of a steel column, a change in temperature of 68·6° F was found to be as dangerous as a compressive stress of 14,400 psi.

When the deviations from straightness due to buckling increase sufficiently, the combination of normal and bending stresses exceeds the yield point of the material, and permanent deformations develop. As large-scale waviness in the walls of high-speed aircraft is most detrimental to the development of the proper aerodynamic forces, more information on thermal buckling is urgently needed.

Experiments carried out with electromagnetic induction-heating units produced large, permanent bulges in the covers of box beams representative of the wing structures of low supersonic-speed aircraft. Solid wedge-type wings showed waviness along the leading edge.

Creep under tension loads:—Besides the loss of strength of metals at high temperatures, creep is an important aspect of their temperature behaviour. If a fighter spends only a few hours of its total flying time at supersonic speeds, and if a guided missile is designed for a flight of only a few seconds or a few minutes, there is every reason to allow stresses in the structure causing creep deformations of a few tenths of a per cent in an hour. If this is not permitted, the allowable stresses must be chosen extremely low when the temperature of the structure is high, and in consequence the aircraft or missile will become unduly heavy. Creep rates of this order of magnitude are unprecedented in the design of structures and machinery.

In a three-bar framework containing a vertical member as well as two members inclined at 60 deg., the vertical member carries 80% of a vertical load when the structure is elastic. For an ideally plastic material, the share of the vertical bar is reduced to 50%. These results indicate that the stress is distributed more evenly when the structure creeps. For this reason, stress concentrations are likely to be less severe in the presence of non-linear creep than in a material following Hooke's law.

Creep buckling:—When a bar is subjected to compressive rather than tensile loads, any slight initial curvature of the centre line of the column gives rise to bending moments. Creep caused by the bending moment increases the curvature and hence the deviation from the straight line. A vicious circle begins, therefore, in which creep is increased by the increased deviations from the straight line and *vice versa*, until the column folds up and becomes useless for structural purposes.

The creep-buckling process takes place under any compressive load, however small. It lasts much longer if the load is small. One cannot talk, therefore, of a critical load or of a critical stress in creep buckling. The

significant quantity is the critical time, i.e., the time necessary for the column to buckle. The structural designer must make sure that the critical time of the column is greater than the required lifetime of the structure.

Conclusions:—The novel feature of the behaviour of structures at high temperatures is the time-dependence of failure. Both in tension and compression the structural element fails under any load if it is maintained for a sufficiently long time. In this respect structures at high temperatures differ fundamentally from those used only at ordinary temperatures. The designer of supersonic aircraft must get used to the idea that each structural element must be calculated for a definite lifetime.

(B) Minimum-Weight Problems[8]

Structural configurations of minimum weight:—To obtain a structure of minimum weight within the limited geometry of thin supersonic wings, the skin acts as the main load-carrying member. As a result, stringer-panel construction is no longer universally used. In its place, various forms of sandwich construction, multicell construction, and post construction have been developed.

To evaluate the newer forms of construction from a minimum-weight standpoint, analytical methods are used. Both the compression cover and supporting structure, such as ribs, webs, and posts, are considered in the analysis. After the nimimum-weight designs have been established, it is then possible to compare the various types of construction on a common basis. From this, the ranges of efficient structural application of each form can be determined.

Relative weights of materials:—The second part of the minimum-weight problem requires evaluation of various materials which may be used at elevated temperatures. The weight-strength evaluation of tension materials is shown in Fig. 5, in which it can be noted that titanium alloy RC-130-A is efficient from room temperature up to 800° F.

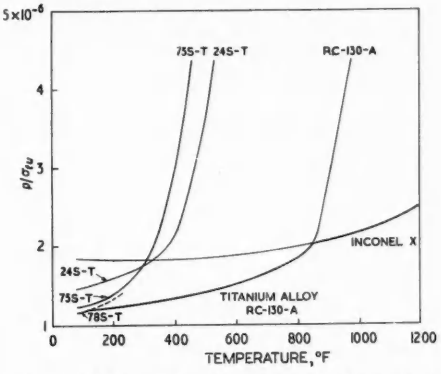


Fig. 5. **Weight/strength ratios for short-time tension loading of various alloys.**
ρ = density; σ_{tu} = ultimate tensile strength.

Components subject to compressive and shear loads are usually governed by buckling considerations. It is usually efficient to use the yield strength as the allowable stress for heavily loaded thin wings. Therefore, a weight-strength evaluation based on plastic buckling at the compressive yield stress is shown for several materials in Fig. 6. Here, it will be seen that, in contrast with the case of tension shown in Fig. 5, aluminium alloys are superior to titanium up to 700° F. Consequently, the apparent superiority of titanium alloys for short-time tension up to 700° F must be balanced carefully against the superiority of the aluminium alloys

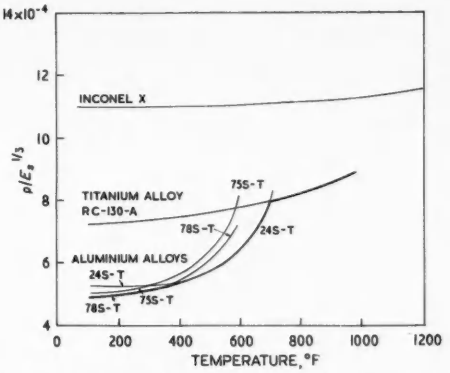


Fig. 6. **Weight/strength ratios for short-time compressive and shear loading of various alloys.**
ρ = density; E_s = secant modulus at yield.

for short-time compression and shear up to 700° F.

Relative-weight analysis:—The natural growth trends of future aircraft are difficult to establish with any degree of accuracy. Therefore, an approach is used in which the weight increases due to elevated temperatures are isolated from the natural growth trends. This has been accomplished by considering the relative weights of two aircraft designed to the same performance specifications; the reference aircraft is designed for room-temperature conditions, whereas the other is designed for elevated-temperature conditions on the basis of short-time strength data.

The increment in structural weight due to elevated temperatures must be multiplied by a suitable growth factor. This factor accounts for the increased propulsive and aerodynamic requirements to achieve comparable performance of the room- and elevated-temperature aircraft. Tremendous weight penalties are apparently involved in the design of aircraft for elevated temperatures in terms of what is now required for the normal-temperature operation of transonic aircraft.

Life expectancy of aircraft:—A new and significant aspect of thermal flight is the time-dependent creep deformation which occurs under applied load. Depending upon the service use of the aircraft, various criteria, such as stress rupture, creep buckling, initiation of third-stage creep, and specified deformations such as 0·02 strain, may be used to indicate the time of retirement of major components of the aircraft structure.

With aircraft at normal temperatures, it is well known that intermittent stresses due to gusts form the basis for limited fatigue-life expectancy. Although relatively little is known about gust conditions in the upper atmosphere, calculations indicate that, under conditions of a 30-fps gust, the resulting stresses may be approximately 50% of the 1-*g* stress level under thermal flight conditions.

Available data on alternating stresses under elevated-temperature conditions indicate that, when the alternating stress level is a fraction of the mean stress, the creep curves remain unchanged to a first approximation. Since the alternating stresses due to gust loads appear to be relatively small, gust loadings may not decrease to any appreciable extent the life expectancy based on the mean stress levels.

To predict the life expectancy of aircraft under elevated-temperature conditions, it is necessary to determine the time required to satisfy a given failure criterion under conditions which involve both varying stresses and temperatures. The initial information for the life-expectancy analysis consists of basic creep data for the material and the relative frequency distribution of applied stress and temperature which the

aircraft is to experience. To determine the life expectancy, a hypothesis is suggested which combines both the loading and physical-property data.

Conclusions:—Sustained flight in the region where aerodynamic heating is of importance may be seriously limited by tremendous weight penalties. Although the upper limit for utilisation of current engineering materials is in the neighbourhood of 1800° F, the weight penalty due to decreased material properties resulting from aerodynamic heating may limit sustained flight to the region below 800° F, which corresponds to a Mach number of approximately 3·5. Flight at higher Mach numbers would be limited to operations of very short duration, so that the structure would not aerodynamically heat up to the steady-state temperature.

In connection with the weight problem, it appears that use of the newer types of construction may result in substantial weight savings for the high-solidity structures required for thermal flight. Under thermal flight conditions, creep will be the determining factor in establishing the practical life expectancy of the aircraft. To design the airframe for an unlimited life will, even if possible, result in additional weight to the already tremendous weight penalties incurred.

DESIGN PROBLEMS[9]

Creep effects:—To some extent, if either the temperature or the stress level is low, creep can be taken care of by merely reducing the allowables. At the higher temperatures and higher stress levels, this leads to such large reductions in material allowables and imposes such large weight penalties that it is no longer feasible and the use of creep data in design becomes mandatory.

A comparison of creep data for wrought and cast materials shows that at the higher temperatures some cast materials have larger allowable creep stresses than wrought materials. If this proves to be generally true, it could mean a radical change in design and fabrication methods, and could lead to the economy associated with castings.

Temperature gradients, stress variations, thermal-induced stresses, stress and thermal cycling, stress-strain-temperature-time histories, and many other factors affect both the stress distribution and the allowable stresses the various components will carry.

Material stability at temperature:—In general, most structural materials lose stability and deteriorate at an accelerated rate at elevated temperatures. The deleterious chemical reactions causing corrosion and loss of stability progress more rapidly at elevated temperatures. Furthermore, the added elements which increase the strength and stability of a material may, at certain temperatures, either precipitate out or unite chemically with other elements and thereby prevent their further functioning in the intended manner.

Losses in strength due to corrosion are generally controlled by either coating the exposed surfaces to prevent the basic alloy from contacting the atmosphere or by adding elements that retard corrosion. At extreme temperatures (above 2000° F) there is a point beyond which alloys, no matter how skilfully blended, can no longer be considered as structural materials.

Apart from metals, the engineer must turn to refractory ceramics, particularly oxides of aluminium, magnesium, silicon, and zirconium. Already fully reacted with oxygen, these oxides can resist corrosive atmospheres and do not weaken appreciably until near their melting points, which may be as high as 5000° F.

Thermal stresses:—Thermally induced stresses depend on the temperature gradient and thus they cannot be reduced or eliminated merely by adding more material. Such stresses are produced by differential expansion; consequently, it would be ideal if a structural material with zero coefficient of expansion could be found or developed. For such a material no thermal stresses would develop, regardless of the temperature distribution.

Nickel, when added to steel in the proper proportion, reduces the coefficient of expansion. The development of low-expansion alloys might well make the difference between a practical aircraft and a structure too heavy to fly. At present, no other metallurgical contribution to high-speed flight appears to offer greater promise or is more within the realm of possibility.

Need for a new criterion of structural safety:—In the design of aircraft structures, a margin of safety is required, to take care of variations in materials, manufacturing techniques, and design uncertainties. The present factor of safety of 1·5 is based on load-carrying ability. In a high-temperature aircraft, however, four important variables are involved: Creep or creep rates, time, temperature, and stresses, any of which can be critical. Fig. 7 shows how confused the margin of safety concept becomes when creep factors are considered.

The conventional 1·5 safety factor applied to the stress is almost ridiculous under the conditions shown in Fig. 7, since it is considerably more than enough to insure " indefinite " creep life. Applying a safety factor to the temperature is equally ridiculous, because even small factors can reduce the stress level as much as, or more than, the conventional 1·5 safety factor used at room temperatures.

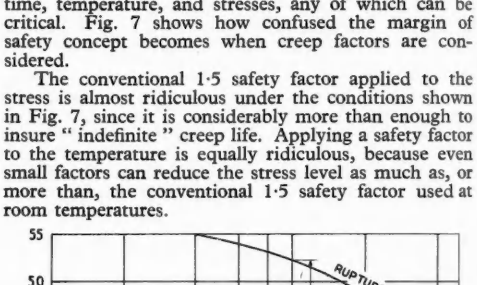


Fig. 7. **Creep curves for 24S-T3 aluminium alloy, showing various ways of applying a safety factor and how allowables are affected.**

Reference to Fig. 7 shows that a 5% reduction in stress permits using the structure 400% longer or reducing total deformation 50%. Thus, small reductions in stress either appreciably increase useful life or decrease total deformation. Also, the 100-hr rupture stress is only 25% above the stress for 1% deformation. Hence, while small reductions in stress appreciably improve the useful life or deformation of structures, they do not compensate much for inaccuracies in structural analysis.

Since the safety factor is so intimately associated with weight, a co-ordinated effort, with the aim of establishing a practical and standardised safety criterion for elevated temperatures, which will remain applicable even after new types of high-temperature material are developed, is needed.

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Brazing Molybdenum for High-Temperature Service

By M. I. JACOBSON and D. C. MARTIN. (From *The Welding Journal*, Vol. 34, No. 2, February 1955, pp. 65s-74s, 19 illustrations.)

The object of the investigation described in this article was the development of methods of producing brazed joints in molybdenum with sufficient strength and ductility to be useful in high-temperature engineering applications. The brazing methods investigated include vacuum brazing in an Inconel retort, oxy-acetylene torch brazing with a flux, and induction brazing in vacuum and in argon.

A REVIEW of available literature on the joining of molybdenum has indicated that the brittleness of molybdenum welds is caused largely by the presence of impurities, both in the base metal and in the weld metal or weld line. Another cause of brittleness in welds in commercial molybdenum is recrystallisation of the base metal.

It was, of course, known that molybdenum could be brazed with several brazing materials. However, there was a considerable lack of information about the room-temperature and high-temperature properties of such brazed joints. Consequently, in this investigation a study of 16 high-temperature brazing alloys was made. The brazing alloys studied were chosen because they had a melting point of 1800° F or higher, and because it was hoped that they would have good strength at elevated temperatures. The composition of the brazing alloys used in this investigation is given in Table I. Many of these alloys were obtained from commercial sources, and were fabricated into foil for the brazing tests. The brazing procedure and test results obtained with these various methods are discussed in this article.

TABLE I. NOMINAL COMPOSITION OF HIGH-TEMPERATURE BRAZING ALLOYS.

Alloy	Composition, %	Liquidus, ° F
Super Nickel 826	70Cu — 30Ni	2240
Nickel	100 Ni	2650
Inconel	80Ni — 14Cr — 6Fe	2540
Chromel	90Ni — 10Cr	2550
Wall Colmonoy No. 6	78Ni — 18Cr — 4B	1950
Monel	70Ni — 30Cu	2370
Hastelloy C	57Ni — 17Mo — 16Cr — 6Fe — 4W	2380
Haynes Stellite 21	60Co — 30Cr — 5Si — 3Ni	2550
Haynes Alloy 25	55Co — 20Cr — 15W — 10Ni	2600
18-8 Stainless	18Cr — 8Ni — Bal. Fe	2600
25-20 Stainless	25Cr — 20Ni — Bal. Fe	2650
Kanthal A-1	70Fe — 25Cr — 5Al	2700
Palladium-Copper	60Pd — 40Cu	2200
Palladium-Nickel	53Pd — 47Ni	2200
Palladium-Silver	60Pd — 40Ag	2500
Silver-Platinum	70Ag — 30Pt	2200

PROPERTIES OF AS-RECEIVED MOLYBDENUM SHEET

Molybdenum sheet for this investigation was ordered from three manufacturers, each of whom supplied eight pieces of sheet $\frac{1}{16} \times 4 \times 18$ in. In this paper, the sheet is referred to as Type A, Type B, and Type C molybdenum. Type A and Type B molybdenum sheets were fabricated from sintered powder compacts, while Type C sheet was fabricated from arc-cast carbon-deoxidised ingots.

The ductility of the as-received sheet was determined by bend tests at room temperature. Test results in Table II show that the sheet had good ductility parallel to the direction of rolling but that ductility was much lower in the transverse direction. Metallographic examination showed that all material was in the typical fibered condition, considered necessary for good bend ductility in commercial grades of sheet.

RECRYSTALLISATION STUDY OF $\frac{1}{16}$-IN. MOLYBDENUM SHEET

It was thought desirable to find out how long each base material could be heated at a given temperature before it recrystallised to the extent that ductility was impaired. Such information would be useful in determining the maximum allowable brazing times. The temperatures chosen were 2400, 2600, and 2800° F. Strips $\frac{1}{2}$ in. wide by $1\frac{1}{2}$ in. long of Types A, B, and C

TABLE II. ROOM-TEMPERATURE BEND DUCTILITY OF AS-RECEIVED $\frac{1}{16}$-IN. MOLYBDENUM SHEET.

Type of molybdenum	Direction*	Deflection rate, ipm	Strain rate, in./in./sec	Bend angle, deg.
B	P	1	0·011	180
B	P	2	0·022	180
A	P	1	0·011	180
A	P	2	0·022	180
C	P	1	0·011	180
C	P	2	0·022	180
B	T	0·5	0·006	67
B	T	1	0·011	65
A	T	0·5	0·006	8
A	T	1	0·011	8
C	T	0·5	0·006	5
C	T	1	0·011	5

* P = Long axis of specimen parallel to direction of rolling.
T = Long axis of specimen transverse to direction of rolling.

$\frac{1}{16}$-in. molybdenum sheets were therefore heated by induction in vacuum at 2400° F for periods of 5, 10, 15, and 30 sec, and 1, 2, 3, and 5 min. The strips were then bend-tested at room temperature at a strain rate of 0·011 in. per in. per sec. Test results showed that Type A sheet could be held at 2400° F for around 2 min; Type B around 1 min; and Type C around 30 sec before room-temperature ductility in the parallel direction was reduced to a value of about one-half that of the as-received sheet. However, at 5 min, each material still exhibited some ductility. Photomicrographs of typical treated specimens are shown in Fig. 1. In general, the microstructures of these specimens could be correlated with the results obtained in the bend tests; in other words, as the amount of recrystallisation increased, ductility decreased.

Similar tests were run at 2600 and 2800° F. However, at these high temperatures the mechanics of the heat-treating process were such that a considerable amount of scatter was produced in the data, and no conclusions could be drawn.

The results of other investigations conducted at Battelle Memorial Institute have shown that recrystallisation alone is not sufficient to cause brittleness. Apparently, brittleness is caused by recrystallisation combined with certain related grain-boundary phenomena. For the purpose of this report, the term "recrystallise" is assumed to include both the recrystallisation of the molybdenum and any associated effects.

RETORT BRAZING TESTS

The first brazing tests were made in an Inconel retort. The apparatus consisted essentially of a Globar-heated resistance furnace, a vacuum pump, and an Inconel retort. The brazing tests were made with Type A and Type B molybdenum sheets.

Prior to brazing, the molybdenum sheet was etched for 10 sec at 190° F in the following solution:— 95 parts concentrated H_2SO_4 + 4·5 parts HF + 0·5 part concentrated HNO_3 + 18·8 gr/litre Cr_2O_3. Both single- and double-lap-type joints were made from $\frac{1}{2} \times 2$-in. strips of sheet. The specimens were assembled with strips of foil placed in the overlapping portions of the joints, clamped in jigs, and placed in the retort. The retort was then sealed, evacuated to a pressure of less than 1 μ and placed in the furnace. Heating proceeded until the temperature in the retort was approximately

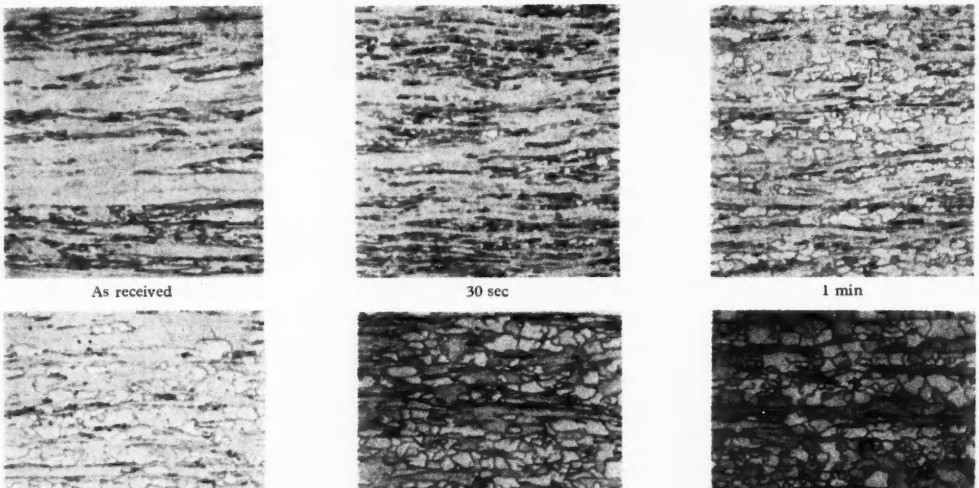


Fig. 1. **Microstructure of $\frac{1}{16}$-in. Type A molybdenum sheet as received and after various times at 2400° F. (× 100).**

100° F above the liquidus of the brazing alloy. After 10 min at temperature, the retort was removed from the furnace and allowed to cool to room temperature before being opened. During heating, the pressure in the retort rose to 4 or 5 μ; however, this did not appear to have any effect on the molybdenum surfaces, as they were still clean and bright after being removed from the retort.

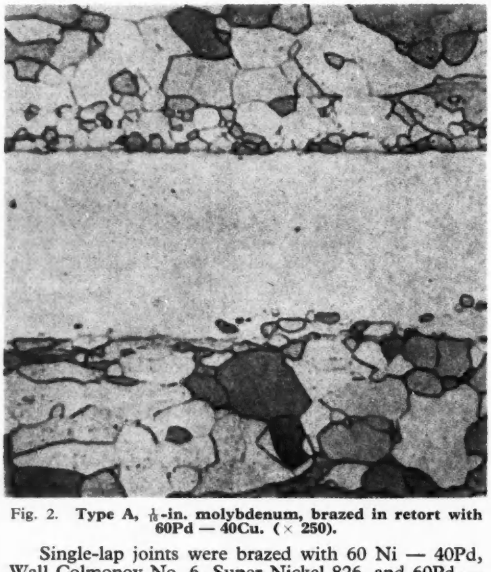


Fig. 2. **Type A, $\frac{1}{16}$-in. molybdenum, brazed in retort with 60Pd — 40Cu. (× 250).**

Single-lap joints were brazed with 60 Ni — 40Pd, Wall Colmonoy No. 6, Super Nickel 826, and 60Pd — 40Cu. Double-shear joints were made with 60 Pd — 40 Cu. A typical photomicrograph of a brazed joint is shown in Fig. 2. The base metal is completely recrystallised because of the relatively long time cycle required to braze a joint in the retort.

The single-lap and double-shear specimens were tension-tested at room temperature in a dynamometer at a speed of 0·150 ipm. Bending stresses were imposed on the single-lap joints during testing, which, combined with the fact that the base metal was recrystallised, caused the joints to fail in the base metal in a brittle manner at relatively low strengths (about 20,000 psi). It was therefore decided to standardise on double-shear-type specimens, in which the testing loads were more evenly distributed. However, these specimens also failed in a brittle manner in the centre strip of base metal at around 23,000 psi. This was due to a combination of the base metal being recrystallised and the notch effect present in the double-shear-type joints.

Since the Inconel-retort apparatus was limited in temperature to brazing alloys melting below 2300° F, and since the long brazing cycles resulted in complete recrystallisation of the base metal, attention was turned to brazing methods which could produce higher temperatures and faster heating rates.

Oxy-Acetylene Brazing Tests

Development of a Flux for Oxy-Acetylene Brazing:—

A few preliminary tests with brazing alloys found to wet molybdenum well indicated that for satisfactory oxy-acetylene brazes a flux would be required. For testing various experimental fluxes, scrap $\frac{1}{16}$-in. molybdenum sheet was used. The fluxes were prepared in paste form and applied liberally to both sides of a strip of sheet. A thin strip of brazing alloy was then placed on the top side of the sheet and covered with flux. The brazing alloys used had liquidus points from 1800 to 2500° F, providing some idea of the temperatures attained in heating. The specimens were heated until the brazing alloy melted and flowed. The flux was then removed by washing in hot water and wire brushing, if necessary. Ease of flux removal and the protection from oxidation were noted.

In order to keep the molybdenum surfaces in the

optimum condition for brazing, it was decided that the flux should offer protection from oxidation from around 800° F up to the melting point of the brazing alloys. Several combinations of commercial fluxes were tried and also combinations of commercial fluxes with additional fluorides and chlorides. In the majority of cases, it was found that the fluxes melted and flowed away from the hot zone before the brazing alloys melted.

After several trials, a flux was compounded which had a wide melting range and which gave fairly good protection up to around 2500° F. The composition of this flux was as follows:—10% boric acid, 6% AgCl, 10% LiCl, 27% Oxweld Brazo flux, 20% NaF, and 27% CaF. In this flux mixture, boric acid (m.p. 350° F) gave low-temperature protection, AgCl (m.p. 840° F), LiCl (m.p. 1130° F), and Oxweld Brazo-Flux (m.p. 950 to 1130° F) intermediate-temperature protection, and NaF (m.p. 1900° F) and CaF (m.p. 2480° F) high-temperature protection. Although the molybdenum appeared to be oxidised, metallographic examination showed little or no evidence of intergranular oxidation and no evidence of attack by the flux. The flux was difficult to remove and did not completely protect the molybdenum. However, it appeared to be satisfactory for the preparation of test specimens. Several double-shear tension specimens for room-temperature tests were therefore prepared with this flux, designated as Flux A.

Further work was done on developing an improved flux which would be easy to remove and which would provide molybdenum with good protection from oxidation. The experimental procedure was changed somewhat, in that the 60Pd — 40Ag alloy, which had a liquidus of 2500° F, was used to measure the degree of flow and wetting, in addition to being an indication of the temperature attained. It was found that the fluxes had better properties if mixed with alcohol rather than water to form a paste. The best flux combination developed was a 50-50 mixture of Eutector 189 and calcium fluoride, used in conjunction with specimens coated with Handy flux. This combination is designated as Flux B. Eutector 189 is a commercial borate-base brazing flux which is active in the range of 1400 to 2000° F. Handy Flux is a commercial borate-base silver-brazing flux melting at 800° F and active up to 1600° F. Calcium fluoride melts at 2480° F, so that Flux B is a wide-melting-range flux offering oxidation protection from around 800 to 2500 or 2600° F. Except for a small area immediately surrounding the solidified 60Pd — 40Ag alloy, specimens heated with Flux B were observed to be very clean and free from oxides, at least on the side on which the brazing alloy was placed. On the opposite side, i.e., the side heated directly by the torch, the degree of oxidation was somewhat greater. In either case, the oxide present could be largely removed by wire brushing and completely removed by an etching treatment. Flux B solidified as a white, granular mass which could be mostly washed off in hot water. The deposit remaining was easily removed by wire brushing.

Oxy-acetylene brazing was also used to prepare joints for elevated-temperature testing. These joints were prepared with Flux B, using Inconel as the brazing alloy. It may be stated that, when Flux B was used to prepare an actual joint, it was not as satisfactory as previous tests had indicated. In making the joints, the flux was heated directly by the torch and for longer periods of time than previously. The molybdenum surfaces were oxidised and the flux was very difficult to remove. Considerable work needs to be done on the development of a satisfactory flux, since oxy-acetylene brazing appears to be one of the more practical joining methods.

Oxy-Acetylene Brazing Procedure:—

Double-shear lap-type specimens were used to determine the room-temperature properties of oxy-acetylene brazes. Brazed joints were made in Types A, B, and C molybdenum sheets. Strips of sheet measuring $\frac{1}{2} \times 2$ in. were cleaned prior to brazing in the etching solution described previously. The strips were assembled with a $\frac{3}{16}$-in. overlap, into which the brazing-alloy foil was placed, and clamped in a jig. The brazing alloys used included 60Pd — 40Cu, 60Pd — 40Ag, Hastelloy C, Haynes Stellite 21, Haynes Alloy 25, 25-20 stainless, 18-8 stainless, Chromel, Monel, and 70Cu — 30Ni. After being covered with generous amounts of Flux A, the joints were heated first on one side and then on the other, until the brazing alloy on each side had melted. Brazing times ranged from 25 to 50 sec.

Results of Oxy-Acetylene Brazing Tests:—

The oxy-acetylene-brazed joints were tested in tension at room temperature in a dynamometer at a rate of 0·150 ipm. The specimens generally failed in the centre strip of base metal at ultimate tensile strengths ranging from 6400 to 80,000 psi, with the majority failing at 40,000 to 50,000 psi. The corresponding shear stresses on the brazes ranged from 1000 to 12,500 psi. However, as the specimens failed in the base metal, no measure of the true shear strengths of the brazes could be obtained.

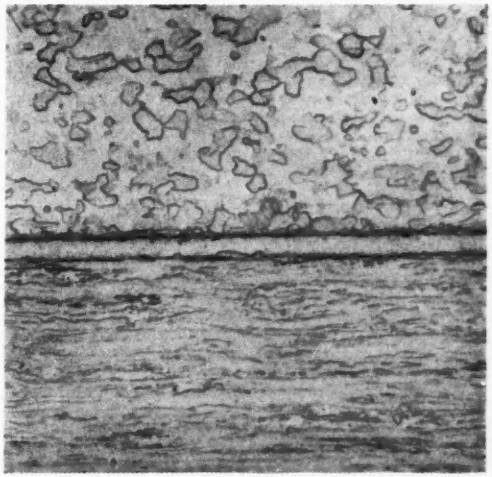


Fig. 3. **Type A molybdenum, oxy-acetylene-brazed with 70Cu — 30Ni. (× 100).**

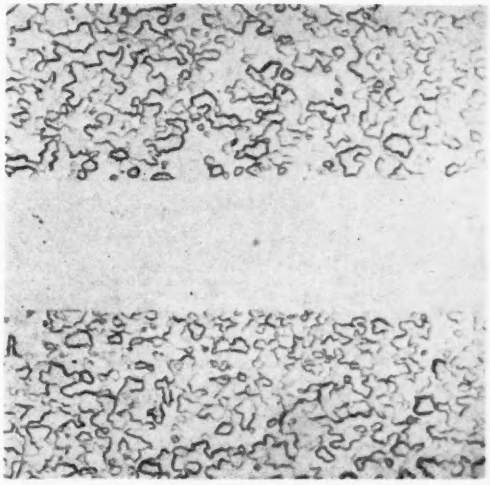


Fig. 4. **Type A molybdenum, oxy-acetylene-brazed with Hastelloy C. (× 100).**

Failure in the base metal was believed to have been induced by a combination of the notch effect present at the joint fillet and recrystallisation of the molybdenum.

Almost all the brazing alloys used in the oxy-acetylene brazing tests flowed and wetted well, with the exception of the 25-20 and 18-8 stainless steels. A metallographic examination of several of the joints showed that good bonding had occurred. Photomicrographs of typical oxy-acetylene-brazed joints are shown in Figs. 3 and 4. As no spacers were used in making these joints, the thickness of brazing alloy present varied from joint to joint. Although this did not have any effect on test results, some type of spacer would probably be required in actual practice, to maintain uniform joint thicknesses. The photomicrographs also show that base-metal recrystallisation and grain growth were not as severe in the oxy-acetylene brazes as in the brazes made in the vacuum retort, in spite of the fact that the oxy-acetylene-brazed joints were made at higher temperatures.

Induction Brazing Tests

An extensive amount of work was done with induction brazing in preparing specimens for room-temperature and elevated-temperature tests, and in developing test specimens that would give the shear strengths of the brazed joints rather than the tensile strengths of the sheet. The induction-brazing apparatus and technique were modified several times during the course of the investigation, to obtain as short a brazing cycle as possible.

Double-Shear Tension Specimens:—

Double-shear-type tension specimens were prepared from Type B molybdenum sheet. After being cleaned by etching, as described previously, the specimens were assembled on a beryllium oxide block. In addition to the brazing-alloy foil, small pieces of 0·003-in. molybdenum were placed in the overlapping portions of the joint to act as spacers and to provide a constant joint clearance. The system was evacuated to 0·2 μ, the induction unit was switched on, and the specimen was heated until the brazing alloy melted. The specimen was held an additional 5 sec to ensure good flow and wetting. Brazes were made with Hastelloy C, Haynes Alloy 25, Haynes Stellite 21, and 60Pd — 20Cu brazing alloys. The time for brazing varied from 25 to 60 sec. The time required to cool to below 1800° F was about 1 min. When tested in tension at room temperature, all the joints failed in the centre strip of base metal at ultimate tensile strengths ranging from 22,000 to 77,000 psi. Photomicrographs of typical induction-brazed joints are shown in Figs. 5 and 6, from which it may be seen that the joint thicknesses were nearly constant.

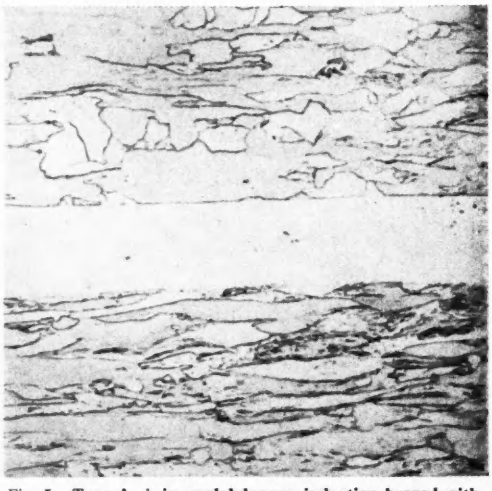


Fig. 5. **Type A, $\frac{1}{16}$-in. molybdenum, induction-brazed with Hastelloy C. (× 100).**

The tensile strengths developed in the sheet averaged 50,000 psi and were generally less than expected, apparently because of notch effects, recrystallisation, and small misalignments of the specimen in testing. Thus, it was not possible to determine the room-temperature shear strengths of the brazed joints by using double-shear joints.

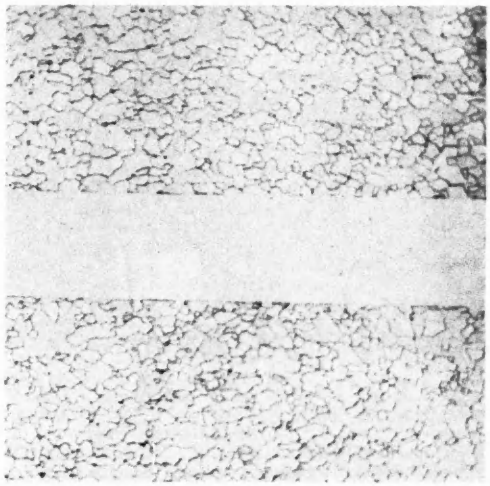


Fig. 6. **Type A, $\frac{1}{16}$-in. molybdenum, induction-brazed with Haynes Alloy 25. (× 100).**

When double-shear joints were induction-brazed in vacuum, it was noted that the time required for the brazing alloy to melt was 25 to 60 sec. Such lengths of time are undesirable in the range of 2400 to 2600° F, as they cause recrystallisation of the molybdenum. Although this is not an important factor in testing, where it is desirable to test the strength of the brazed joint rather than the strength of the sheet, it is important from a practical standpoint. In order to try to reduce the time required for brazing, the induction-brazing apparatus was modified a number of times. An atmosphere of flowing argon was used rather than a vacuum, with no adverse effects on the molybdenum surfaces. With the new arrangement, it was possible to melt the brazing alloys in 5 to 6 sec, rather than in the 25 sec or longer previously required. Specimens were held at temperature for 5 sec after melting of the brazing alloy, to ensure good flow and wetting. The time required to cool to below 1800° F was reduced to 20 sec.

Slotted-Type Tension Specimens:—

The need for a test specimen which would cause brazed joints in sheet to fail under conditions approaching pure shear, and which would have no severe notch effects, resulted in the development of so-called slotted tension specimens, made from Type A sheet. These specimens were assembled by wrapping 0·003-in. brazing-alloy foil around the end of the unslotted piece and slipping it into the $\frac{1}{8}$-in. slot. A room-temperature tension test was made with a specimen induction-brazed in argon, using Monel as the brazing alloy. The specimen failed in the base metal at an ultimate tensile strength of 35,000 psi. The test result and manner of fracture indicated that a notch effect was still present at room temperature.

It was believed that the notch effect might be re-

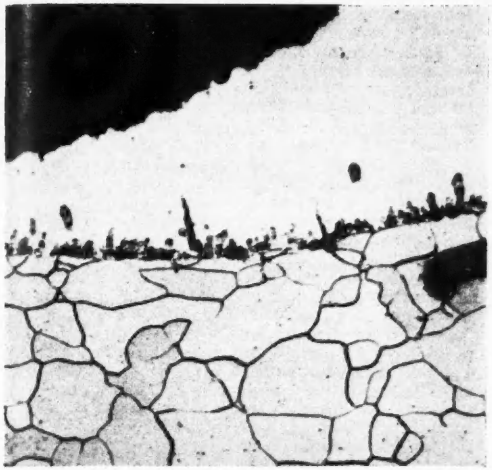


Fig. 7. **Type A molybdenum, induction-brazed with Hastelloy C and tested at 1800° F. (× 250).**

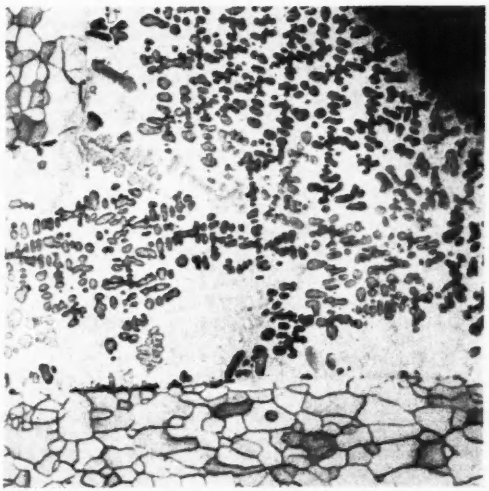


Fig. 8. **Type A molybdenum, induction-brazed with Inconel, as brazed. (× 100).**

duced considerably at 1800° F. A slotted-type specimen was induction-brazed in argon, using Type A sheet and Hastelloy C as the brazing alloy. The brazed specimen was loaded to failure in a vacuum creep furnace at 1800° F, merely to observe the manner of fracture. When the specimen was removed from the testing apparatus and examined, it was seen to have failed in shear. The unslotted piece had been pulled out of the slotted piece. Thus, since failure occurred by shear in the braze area, rather than by tension in the sheet, the actual shear strength of such brazed joints could be calculated.

It was decided to make short-time tensile tests at 1800° F on the slotted-type specimens brazed with several different alloys. On the basis of the test results, one cobalt-base and one non-cobalt-base brazing alloy would be selected to braze specimens for 100-hr stress-rupture tests.

Short-Time Tension Tests at 1800° *F*:—

Ten slotted-type tension specimens were prepared for short-time tensile tests at 1800° F by induction brazing in an argon atmosphere. The molybdenum used was Type A sheet, which was chosen on the basis of its resistance to recrystallisation. The brazing alloys were in the form of 0·003-in. foil. The brazed specimens were tested by placing them in the vacuum creep furnace, evacuating the furnace, heating to 1800° F, and loading the specimens until failure occurred. All specimens failed in the brazed joint, and from the load at failure the shear strengths were calculated, ranging from 3400 psi for Kanthal A-d to 18,800 psi for Inconel, suggesting that the best non-cobalt-base alloy was Inconel. The best cobalt-base alloy was Haynes Alloy 25 (14,250 psi).

In the case of Inconel and Monel, the shear strengths of the brazes were considerably higher than the tensile strengths of wrought sheet, while for Haynes Stellite 21, Haynes Alloy 25, and Hastelloy C the shear strengths of the brazed joints were lower. A metallographic examination was made of all of the brazed specimens after they had been tested. For Inconel and Monel, there was evidence of considerable diffusion of molybdenum into the brazing alloy, which might explain the increase in elevated-temperature strength of the brazed joint, as compared with the strength of the alloy alone. With Haynes Stellite 21, Haynes Alloy 25, and Hastelloy C, the lower strengths of the brazed joints may be due to the formation of a brittle compound in the bond area. Photomicrographs of the bond area in two of the fractured tension specimens are shown in Figs. 7 and 8.

Stress-Rupture Tests at 1800° *F*:—

On the basis of the results obtained in the short-time tensile tests, Inconel and Haynes Alloy 25 were selected as the brazing alloys to be used in making 100-hr stress-rupture tests. The base metal was $\frac{1}{16}$-in. Type A sheet, of which four slotted-type specimens for each alloy were induction-brazed in argon. The time required for the Inconel to become molten was 6 sec, and for the Haynes Alloy, 5 sec. After the brazing alloy had melted, the specimens were held at temperature for 5 additional seconds to ensure good flow and wetting. Oxy-acetylene brazing was also used to prepare four slotted-type tension specimens, using Inconel as the brazing alloy and Flux B. These specimens required approximately 1 min to braze.

In making the stress-rupture tests, the specimens were placed in the vacuum creep furnace, heated to 1800° F, and loaded to preselected stress levels below the short-time shear strengths of the brazes. The specimens were held under these conditions until failure occurred.

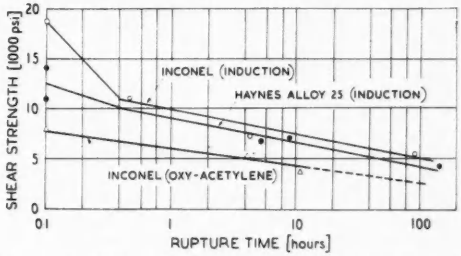


Fig. 9. **Stress-rupture curves at 1800° F for brazes made with Inconel and Haynes Alloy 25.**

Fig. 9 shows stress-rupture curves at 1800° F for brazes made with Inconel and Haynes Alloy 25. The 100-hr strength of joints brazed with Haynes Alloy 25 was found to be around 4500 psi, which compares with the 100-hr strength of 10,000 psi for Type A molybdenum sheet and 10,500 psi for wrought Haynes Alloy 25 sheet. The 100-hr strength of induction-brazed Inconel joints was about 5000 psi, while the figure for oxy-acetylene-brazed joints was approximately 2500 psi. The induction-brazed joints thus had a 100-hr shear strength approximately 50% of the 100-hr stress-rupture strength of wrought molybdenum sheet at 1800° F.

Effect of Brazing Cycle on Microstructure and Brazing-Alloy Composition

As mentioned in the previous section, the slotted-type tension specimens brazed with Inconel and Haynes Alloy 25 were prepared by heating until the brazing alloy melted (5 or 6 sec), and then holding for 5 sec. The temperatures attained were approximately 2700° F, and, although the brazing time was very short, metallographic examination showed that the base metal had nevertheless recrystallised 100%. This suggested that the 5-sec holding time might be too long. Four slotted-type specimens were therefore induction-brazed in argon, using Type A sheet and Inconel as the brazing alloy. The specimens were heated until the Inconel melted, which required 6 sec, and were then held at the melting point for 0, 1, 2, and 3 sec. Photomicrographs of the specimens are shown in Fig. 10. The degree of

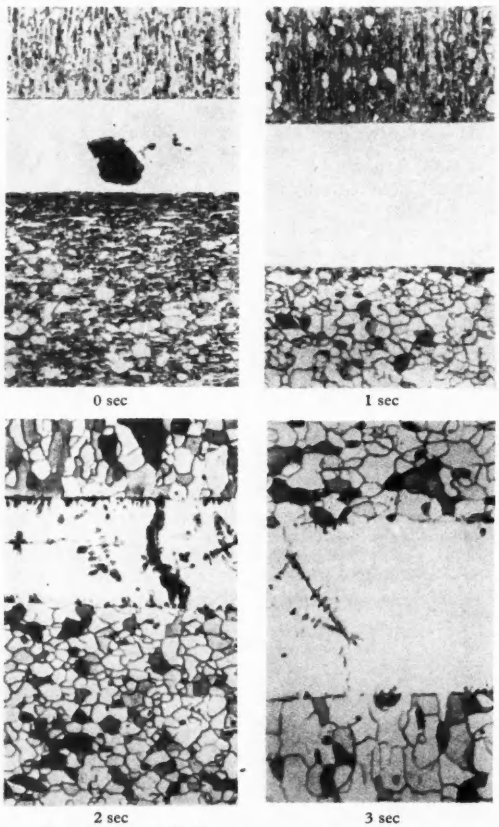


Fig. 10. **Effects of holding time on Type A molybdenum joints, induction-brazed with Inconel. (× 100).**

recrystallisation of the base metal was found to range from about 20% for the 0-sec specimen to 100% for the 2- and 3-sec specimens. However, the recrystallised grain structures were relatively fine, indicating that the base metal might have good ductility. In examining the Inconel in the joints, it may be seen that, for the 0- and 1-sec holding times, no second phase is present. However, for the 2- and 3-sec holding times, a second phase is present in the Inconel. This is also shown in Fig. 8, which is an induction brazed joint in Type A molybdenum in which the Inconel was held molten for 5 sec. It is believed that this second phase is caused by molybdenum diffusing into the Inconel during brazing. This might explain the observation that the short-time tensile strength of rolled Inconel sheet at 1800° F is 7500 psi, while the short-time shear strength of a joint brazed with Inconel is 18,800 psi at the same temperature. Further evidence of diffusion of molybdenum into the Inconel was obtained by making tests to determine the remelt temperature of joints brazed with Inconel and by measuring the hardnesses of the Inconel. The procedure for determining remelt temperatures was to prepare a single-lap joint by induction brazing, using a holding time of 5 sec. This single-lap joint was suspended vertically in an induction heating apparatus used to determine the melting point of metals and alloys. The joint was heated until the brazing alloy became molten and the two pieces separated. This occurred at a temperature of approximately 3100° F, as compared with the melting point of 2540° F for Inconel alone.

Vickers hardness readings were made on the Inconel in the joints held at brazing temperature for 0, 1, 2, 3, and 5 sec. The hardness of the Inconel increased from 330 Vhn for the 0-sec specimen to 667 Vhn for the 5-sec specimen. It is therefore apparent that joints brazed with Inconel owe their high strength to the diffusion or alloying of molybdenum and Inconel. Thus, although shorter holding times will reduce the degree of recrystallisation of the base metal, a 5-sec holding time is apparently required to obtain high strength, at least in the case of Inconel.

Fields for Further Study

It has been demonstrated that molybdenum can be joined readily by furnace brazing in vacuum, oxy-acetylene brazing with a flux, and induction brazing in vacuum or argon. From the standpoint of quality and practicability, induction brazing in argon appeared to be the most suitable brazing method. It must be pointed out, however, that the use of induction brazing in actual practice would be limited by the size and shape of the piece being formed. With induction brazing, joints were made which had excellent strength and stress-rupture properties at 1800° F. However, the creep properties of the brazed joints were not determined, and this information is necessary before brazed molybdenum can be considered for elevated-temperature structures.

Strength tests were limited to 1800° F. Further tests should be made at higher temperatures.

A testing problem in the evaluation of brazed joints is the difficulty in measuring the ductility of the brazing material itself. Although bend tests can be made on the base metal immediately adjacent to the brazing alloy, no measurements of brazing-alloy ductility are possible. The development of a method or type of specimen for measuring ductility in brazed joints would be helpful.

In brazing molybdenum, it might be desirable for certain applications to keep recrystallisation of the base metal at a minimum in order to maintain good ductility. With commercial grades of molybdenum, it was practically impossible to prevent recrystallisation at the high brazing temperatures used, even though the time at temperature was only a few seconds. One method of preventing, or retarding, recrystallisation would be to develop a brazing alloy with a melting point of 2400° F or less, with high-temperature properties equal to or better than those of Inconel or Haynes Alloy 25. The alloy should be capable of being rolled into brazing foil and should react with molybdenum in a manner similar to that of Inconel. Another method of preventing recrystallisation would be to use a molybdenum-alloy base metal with good resistance to recrystallisation. Experimental alloys of this type are already being investigated, and molybdenum-titanium alloys, with recrystallisation temperatures of 2600° F, can be obtained commercially.

Since oxy-acetylene equipment is relatively inexpensive and readily available, it might be desirable to investigate oxy-acetylene brazing further.

British Industrial Developments

New Phosphor for Radar Tubes

The recent development of short-range navigational radar for use in estuaries and crowded shipping lanes has called for cathode-ray tubes with unusual screen characteristics. In these systems, signals reflected from ships or coastlines are used to " paint " a picture of the area round the vessel within a radius of, say, a quarter of a mile, on a tube screen. Tubes such as those already in use for long-range radar are unsatisfactory, because their afterglow persists for about 30 seconds. The picture of the sea some 30 or 40 miles away does not change very much in this period but, at a range of a quarter of a mile, it may change considerably, owing to the greater relative speeds of movement. Furthermore, if a ship fitted with short-range radar " yaws," pictures received on successive rotations of the aerial, i.e., every two or three seconds, would, with a normal tube, be superimposed on one another in a confused jumble which would not clear up until the vessel returned to a straight course and an even keel.

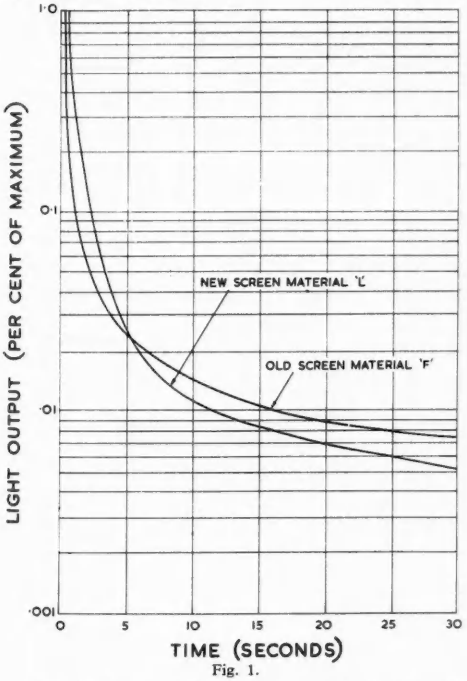


Fig. 1.

For short-range radar, tubes are therefore needed which give a picture which persists brightly for two or three seconds and then fades out rapidly before the next picture is painted. A further requirement is that the picture should be as sharp and clear as possible. One device which has been used for obtaining the required afterglow characteristics is the double-layer screen. The electron beam of the radar tube strikes the first layer of such a screen to produce ultraviolet or near-ultraviolet light, which in turn excites the front screen to produce the visible picture. Unfortunately, since the light originates at a point a few millimetres behind the actual viewing screen, it is scattered to some extent by the time it reaches the screen. As a result, the picture lacks definition.

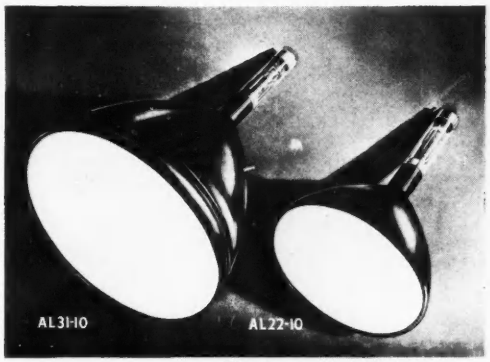


Fig. 2.

In some recently introduced radar tubes, Mullard Limited have employed a single-layer screen made of a special grade of magnesium fluoride. This has the required afterglow characteristics and at the same time gives the sharply defined picture necessary for short-range work. In addition, the new tubes, types AL22-10 (9-in.) and AL31-10 (12-in., flat-faced), have a special low-voltage electrostatic-focus lens which makes the realisation of maximum definition much easier than with magnetic focus. The new phosphor has the advantage that the initial brightness is greater than that of double-layer screens. After the first few seconds, however, the light decays very rapidly. Comparative phosphorence of old and new Mullard radar-screen tube materials is shown in Fig. 1.¶ The new tubes (Fig. 2) may also be used in long-range radar systems where plotters are provided.

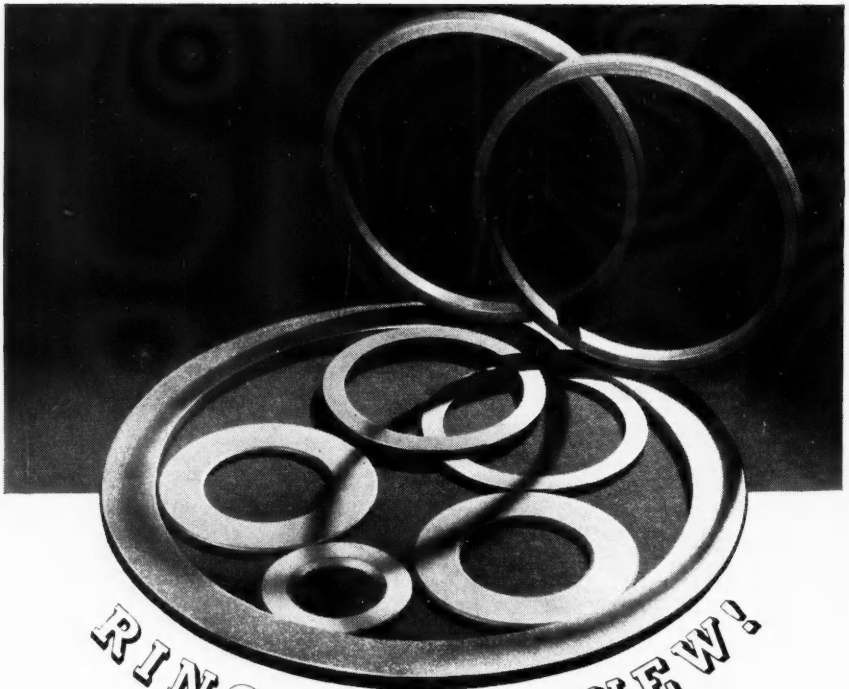
Application of Semi-Solid Anti-Corrosive Compounds by a Hot-Spray Process

A hot-spray method for applying semi-solid anti-corrosive compounds has been developed as a result of co-operation between the Regent Oil Co. Ltd. and the Atlas Diesel Co. Ltd.

The difficulties of effectively spraying such compounds are well known and more often than not excessive quantities of thinners are required. Consequent evaporation after application may result in an inadequate coating, as well as contamination of the atmosphere with solvent vapours. The other and normal alternative is to apply the compound with a brush. This method is time-consuming and often quantitatively wasteful, besides giving an uneven finish and insufficient coverage in spots not easily accessible with a brush.

The newly developed hot-spray process is the result of experiments with the Regent Oil Co.'s Caltex Rust-proof Compound L and the Atlas Diesel Co.'s KV3 Cup Heater and Ecco 306 Spray Gun. The compound, which contains 12% volatile thinner, is heated in the cup heater to between 140 and 160° F, and is sprayed at a pressure of 45 psi by the special internal-mix Ecco 306 gun, which gives the required atomisation. When the globules strike the surface being sprayed, they congeal immediately, thus eliminating wasteful back-spray, resulting in an even coating with effective cover.

Compound L, a semi-solid, is a blend of mineral oil and petroleum jelly, containing special additives which give it non-drying, flexible, and high adhesive qualities,



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thus providing a protective coating or film which does not harden or crack, and which will withstand rough treatment and tropical or arctic temperatures. None of these qualities is lost by use of the hot-spray method. An advantage of Compound L is that it can be sprayed on a surface that is not completely free from moisture.

As these experiments have recently been completed and as the field of application ranges from steel bridges and car chassis to machine tools, each requiring a different thickness of protective coating, it is not possible at this stage to give accurate costing figures. However, it is expected that considerable economy in both time and materials will be effected.

Soak-Test Conveyor for Television Production

At the Romford factory of Regentone Radio & Television Ltd., where large quantities of television and radio sets are produced each day, a new " soak-test " conveyor has been installed to speed up the testing of television chassis before final assembly and despatch.

For the satisfactory testing of newly assembled television chassis, several hours of continuous operation are necessary, since it is during this period that any faults in new sets are normally discovered by the purchaser. The ever-increasing rate of manufacture at the Regentone factory made the stationary testing of assembled chassis for this period a drag upon the production line and the soak-test conveyor has been introduced to speed up this part of the process. A general view of the conveyor in operation is shown in Fig. 1.

Supplying electricity to the individual chassis whilst in motion presented a problem which has been successfully overcome by the use of miniature current-collection arms running along hard-drawn copper bars, as shown in Fig. 2. Each bank of three television chassis is supplied *via* two of these miniature arms, which are completely swivelling and are particularly suitable for installations of this kind, having been specially developed

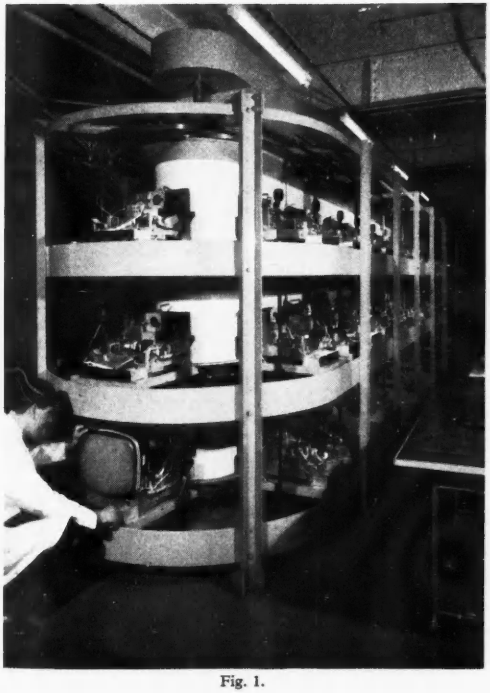

Fig. 1.

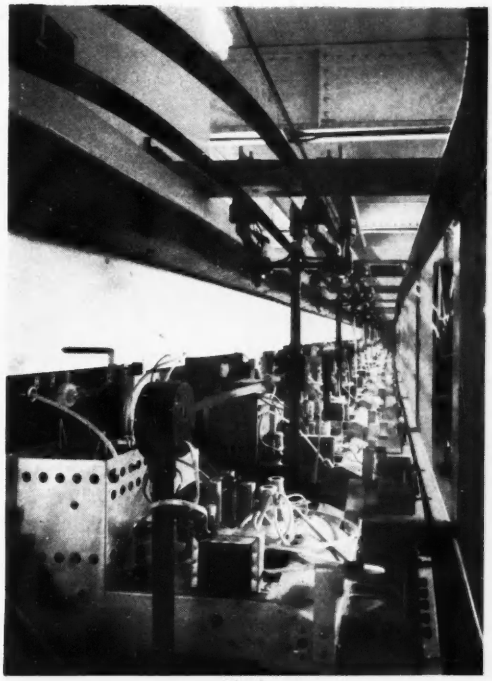

Fig. 2.

by British Insulated Callender's Cables Limited, who co-operated with Regentone in the design and installation of the current-collection equipment.

To minimise the risk of sparking, which would cause unwanted interference to the sets, each miniature arm is fitted with a carbon-insert slipper head. A feature of the electrical equipment is that multi-coloured pilot lights are installed to give notice of any faults and to indicate which part of the circuit needs attention.

Flexible Hoses for High-Test Hydrogen Peroxide

The problems and dangers of handling high-test hydrogen peroxide (H.T.P.) by " flexible " means have now been overcome by the Flexible Advisory Service of the Compoflex Co. Ltd., of London, S.W.1. After intensive research, the company has produced an approved range of thin-walled flexible hoses, all entirely compatible with H.T.P., together with a range of ancillary equipment, including O-rings and specially developed non-creep gaskets for use with these hoses.

Basically, the hoses are made of terylene and specially compounded P.V.C., rendering them flexible over a wide range of temperatures, extremely hard-wearing, light, and strong. Previous H.T.P. flexible hoses were made entirely of P.V.C., but they have not proved very satisfactory in service, owing to a lack of flexibility in cold weather, a liability to kink and collapse, and a relatively short life.

Two types of H.T.P.-carrying hoses are now available, each ranging in size from 1 to 3-in. internal diameter. The first type is a wire-supported hose for suction or delivery, consisting of a layer of specially compounded P.V.C., known as Molene, covered with a layer of terylene which has been coated on both sides with the same special P.V.C. mix. Over this is wound an austenitic stainless-steel wire spiral covered with

(*Concluded on page* 128)

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CLASSIFIED ABSTRACTS

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AUTOMOBILE ENGINEERING

Assessment of Car and Fuel Factors Affecting Vapour-Locking Tendency.

By G. F. SHEPPARD and J. G. WITHERS. (From an advance copy of a paper submitted to *The Institution of Mechanical Engineers, London*, February 1955, 8 pages, 10 illustrations.)

"VAPOUR LOCK" may occur anywhere in a fuel system, although petrol-pump vapour lock is generally the most serious. The most common form of this trouble is that which arises when attempts are made to re-start a car which has been stationary for a few minutes, after having been previously driven at sustained high speed.

In this paper, the mechanism of vapour lock is shown to depend both upon the amount of vapour formed and the ability of the fuel system to handle vapour, but the greatest improvements are likely to be made in reducing the amount of fuel vapour formed. The effects of temperature, pressure, and fuel volatility on vapour formation are discussed, including the conflicting volatility requirements for freedom from vapour lock on the one hand, and good starting and warming-up characteristics on the other.

It is shown that distillation and vapour-pressure characteristics are not suitable criteria for quality-control purposes, and that only by the laboratory determination of vapour/liquid ratio (V/L) versus temperature relations can a proper estimate of fuel vapour-locking tendency be obtained. Laboratory apparatus for determining V/L ratios is described, and results for some fuel combinations are presented.

The various driving conditions encountered in service are discussed in relation to their effects upon vapour-locking tendency. Open-road driving at full throttle, followed by a stationary "soaking period," during which the under-bonnet temperatures rise to maximum values, is a very severe condition, but hill-climbing or city traffic conditions may be just as severe. A full-throttle soak-test method for the determination of the volatility tolerance of cars on the road, making use of a double series of reference fuels, is described; it is shown how the results may be interpreted in terms of the ambient temperature for freedom from vapour lock, using any given fuel. A description is also given of a simplified road technique, using a single series of reference fuels. This test technique requires no vehicle instrumentation, and a predetermined V/L- ratio framework may be used to interpret the results.

The Cause and Correction of Carburetter Gumming.

By H. W. SIGWORTH and J. Q. PAYNE. (From *Automotive Industries, U.S.A.*, Vol. 111, No. 12, December 15, 1954, page 55, 2 illustrations.)

IN a recent investigation of faulty carburetter operation, rough rich idling and engine stalling in service vehicles indicated that the main cause was a deposit in the carburetter throttle body. In most instances, the typical deposit was a ring of dry, carbonaceous material on the throttle-body wall opposite and below the closed (idle) position of the throttle plate. This carburetter gum deposit restricted the flow of air past the edge of the throttle plate during idling, enriching the mixture to the point where carburetter adjustment became necessary every 5000 to 7000 miles, and cleaning every 15,000 to 20,000 miles.

The contribution of "blow-by" was then proved by significant observations and tests. Results showed that: (1) Blow-by markedly increases carburetter gumming, accounting for 40 to 60% of contamination; (2) in normal service, an appreciable portion of the blow-by still finds its way into the air intake, causing one-half of the carburetter gum; (3) induction of intake air from outside the engine compartment reduces, but does not completely eliminate, carburetter gumming, indicating that contaminants other than the car's own blow-by contribute to carburetter gumming; (4) during idling, the air flow through the air cleaner is too low to separate intake-air contaminants. Smoke and dust contribute 5 to 25% and exhaust from other cars 5 to 40%.

The mechanism of carburetter gumming may be summarised as follows:—Carburetter gumming occurs during idling because (1) the closed throttle position sets up high velocities around the throttle-plate edge, separating entrained materials; (2) blow-by concentration in the atmosphere under the bonnet is at a maximum; and (3) the velocities through the air cleaner are apparently too low to separate the contaminants.

The most effective and economical solution to the carburetter-gumming problem is the use of detergent-action gasolines, which remove carburetter gum deposits during normal vehicle operation.

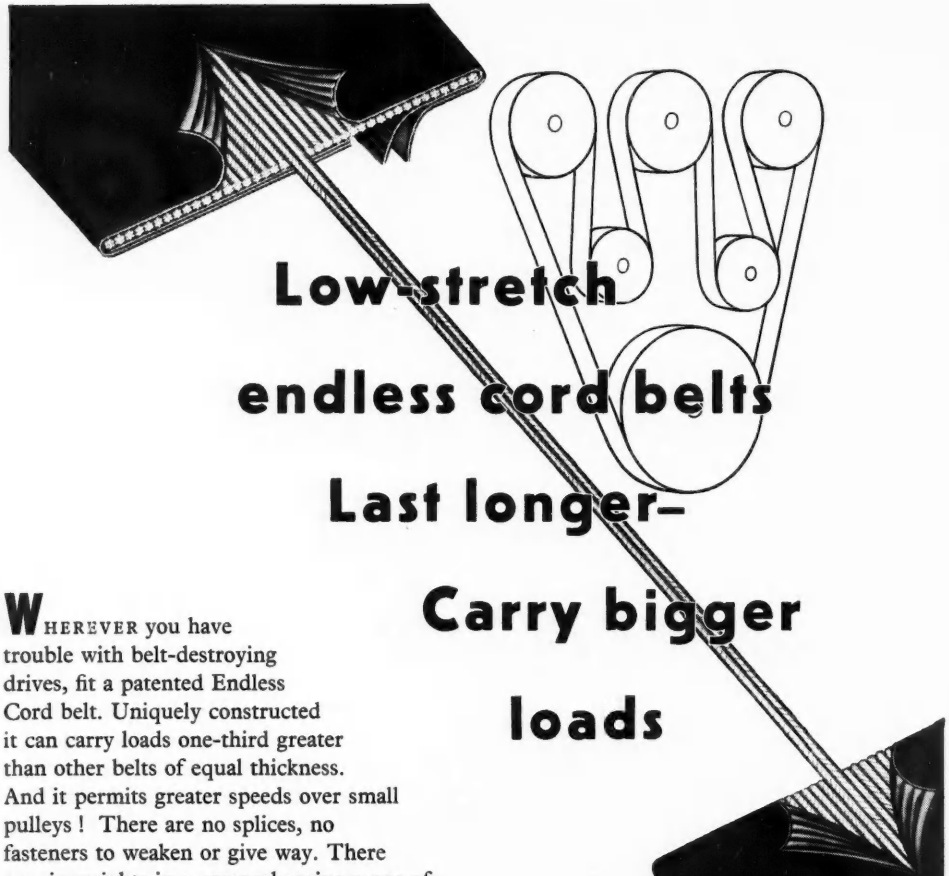
CHEMICAL ENGINEERING

Advantages of Titanium in the Chemical Industry.

By W. G. RENSHAW and P. R. BISH. (From *Corrosion, U.S.A.*, Vol. 11, No. 1, January 1955, pp. 41t-47t, 6 illustrations.)

THE potentialities of titanium as a construction material for the chemical industry are quite promising, but its use in this field has been restricted by short supplies and high prices. The attractiveness of titanium originally lay in its usefulness as a load-bearing structural material for aeronautics, where its high strength/weight ratio was most advantageous. To-day, titanium is close to commercial realisation in that almost every form of wrought material—plates, sheets, bars, wire, forgings, etc.—is in regular mill production in fairly large quantities. The excellent corrosion resistance of titanium later became an added incentive for commercial development but, until the demands for strategic applications are met, research will be almost exclusively directed toward high-strength alloys for aeronautical uses or those with high impact strength for ordnance applications. There will probably be little consideration given to the specific needs of the chemical industry or to non-military uses for some time. However, the corrosion-resisting characteristics of titanium should be of interest to the chemical industry, should developments cause a marked change in availability and price.

At present, there are no alloys of titanium available with any special properties of interest to the chemical industry. However, the commercially pure grade of the metal is resistant to a wide range of corrosive substances, and is superior to other metals under certain special operating conditions. It is in these special cases that titanium can pay its way satisfactorily, because of certain unique corrosion-resisting characteristics



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In this article, the more valuable properties of titanium are discussed, with emphasis on its good resistance to specific types of corrosion, including pitting, stress, and intergranular corrosion. The passivity of titanium under oxidising conditions resembles that of certain other metals, but is distinctly different under some conditions. Conditions which promote passivity and a stable passive state are discussed. Inhibitors are unusually effective in certain corrosive media where other passive metals are not benefited. Studies of the passivating characteristics of titanium and the presence or absence of certain components in the environment may explain behaviour of the metal in dry halogens and certain other media. Moist environments appear to be conducive to passivity, while the reverse is often true for other metals in some of these severe applications.

EXPLOSIVES

Effects of Underwater Explosions on Elastic Structures in Water.

By E. ENHAMRE. (From *Acta Polytechnica, Sweden*, Physics and Applied Mathematics Series, Vol. 2, No. 12, 1954, 79 pages, 39 illustrations.)

IN the course of the detonation process, an explosive material is transformed into gaseous products which ultimately reach a temperature of the order of 3000° C and a pressure of the order of 50,000 kg/cm². The state of equilibrium of the detonation products represents an internal energy which is lower than that of the initial explosive material. The difference is the amount of energy released, which manifests itself in an enormous increase in the pressure and the temperature of the detonation products.

The pressure disturbance initiated at the instant when an explosive charge detonates is propagated in all directions, and the pressure decreases as the distance from the detonation centre becomes greater. The pressure/time curve at a point situated outside the charge comprises two branches, i.e., a rising pressure branch, in which the pressure increases to its maximum value in about one microsecond, i.e., practically instantaneously, and a falling pressure branch, in which the pressure decreases approximately in accordance with an exponential law.

In this paper, after a brief description of the loads caused by underwater explosions, an expression for the correction of the pressure acting on a surface in water for the motion of this surface is analytically deduced. The sum of the pressure exerted by an underwater explosion on a structure in water and the correction pressure due to the motion of the structure constitutes the load acting on the structure. The deformations of a clamped circular steel plate submitted to this load have been calculated analytically and investigated experimentally, and these results are compared.

The principle of similarity is used for evolving a method of calculating the relation between loads and strains for plates having the same diameter/thickness ratio as those plates for which the corresponding relations have been determined by tests.

FLOW OF FLUIDS

Pulsating Flow Measurement by Viscous Meters.

By L. J. KASTNER and T. J. WILLIAMS. (From a paper presented at a meeting of *The Institute of Mechanical Engineers, London*, February 18, 1955, 16 pages, 13 illustrations.)

THE problem of measuring the mean rate of mass flow of a fluctuating stream is one which has attracted the notice of many investigators but, although a limited degree of success has been achieved by more than one method, it may be said that a simple, inexpensive, and compact device capable of dealing with flows subject to severe pulsations without loss of accuracy and without ancillary apparatus has yet to be described. Meters of the orifice type, used in conjunction with large smoothing capacities, have been widely employed, in particular for the measurement of the air consumption of reciprocating internal combustion engines, but the smoothing capacity required is often inconveniently great, and too small a volume will lead to surprisingly large errors, whilst the range of flows covered by a single orifice is rather restricted, since the rate of flow is proportional to the square root of the head. Electrical methods, depending on the transfer of heat from an electrically heated wire to the stream, have been tried, but are also not free from errors when velocity fluctuations are present. Other methods adapted to particular circumstances have had some success, but do not represent a satisfactory general solution of the problem.

So-called "viscous meters", in which the pulsating stream is directed through a number of narrow passages, across which the pressure difference is measured, and in which the Reynolds number is kept so low that the flow is laminar, may be shown theoretically to have certain advantages, notably that of a straight-line law between head and mass flow, even when the instantaneous velocity is subject to fluctuations. Within limits, these advantages have been confirmed in practice but, under conditions of severe pulsation, such meters have shown large and puzzling errors.

The investigation described in this paper was undertaken with the primary aims of studying the performance of viscous meters under the most severe conditions of pulsating flow, with special reference to the measurement of the air consumption of reciprocating internal combustion engines, and of developing an accurate meter suitable for use under such conditions. It is believed that these aims have been at least partly achieved and, whilst many of the experiments relate to engine airflow measurements, it is considered that the results are capable of wider application and that they will be of value in a variety of problems concerned with fluctuating flows.

FLOW MECHANICS

Surge in Compressors and Jet Engines.

By C. E. PEARSON. (From *Journal of the Aeronautical Sciences, U.S.A.*, Vol. 22, No. 1, January 1955, pp. 10-16, 1 illustration.)

COMPRESSORS and jet engines are occasionally subject to a form of instability called surging, which usually occurs near the peak of the pressure-flow characteristic and which seems to involve an overall oscillation of flow.

The analysis described in this article deals with a theoretical model of a jet engine (or compressor, as a special case) consisting of a compressor, a "burning" chamber, in which heat but not mass is added, and an exit nozzle which is assumed choked, so that the turbine has no aerodynamic coupling to the compressor. Shaft coupling between turbine and compressor is assumed to have only a secondary effect on the incidence of surge. A number of idealisations (such as the assumption that burner temperature varies linearly from inlet to exit) is made, in order to render tractable the manipulation of the mass and energy conservation equations as applied to each element of the model.

Experiment indicates that the character of the airflow in the compressor under transient conditions depends only on the instantaneous flow rate and the rotational speed of the compressor; this generalisation permits a type of entropy conservation theorem to be written for the compressor section. The resulting set of ordinary differential equations must be obeyed by the airflow at all times. Because of the non-linearity of the equations, a direct instability analysis is not feasible; therefore, it is

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assumed with reasonable justification that, if a solution becomes unstable, then so too does any perturbation in this solution. The instability of the set of linear equations resulting from perturbation of the original equations is examined, and three analytical criteria obtained.

INTERNAL COMBUSTION ENGINES

Failure of Diesel-Engine Pistons and Cylinder Covers.

By D. FITZGEORGE and J. A. POPE. (From a paper presented at a meeting of the *North-East Coast Institution of Engineers and Shipbuilders, Newcastle-upon-Tyne*, February 11, 1955, pp. 163-236, 55 illustrations.)

IN the research described in this paper, carried out on behalf of the British Shipbuilding Research Association, the stresses occurring in combustion-chamber parts are discussed with regard to their nature, magnitude, and likely contribution to failure. The physical and mechanical constants of the material which affect the thermal stresses are given, and the modifying influence of plastic deformation is considered.

It is deduced that cracks which commence at the hot side of the walls are due to residual stresses on cooling down, following plastic flow while running. This form of crack is shown to be most likely to occur in cast iron (where ductility is low) and the authors have not so far encountered it in steel components. The danger spots are in the hot face of the cover (particularly where high thermal compressive stresses occur initially as a result of asymmetry) and in the hot face of the piston crown.

The second principal cause of failure is the fatiguing action of the repeated combustion pressures, combined with the tensile stresses occurring as a result of temperature gradients in the walls. The cracks occur at the horizontal junction of the crown and wall of pistons, and where webs and other scantlings meet the cover plate in cylinder covers. Failures of this type commence at the cooled side of the walls and occur in steel as well as in cast-iron components.

The effects of growth, additional stresses accompanying load changes, and the fluctuating surface stresses caused by the varying gas temperature are small, but the authors prefer to regard them as contributing factors causing somewhat earlier failures. Typical failures are discussed. Radial cracks in cylinder covers and circumferential cracks in pistons are selected for detailed study. Direct estimates of the initial thermal compressive stresses in an unsymmetrical cover range from 16 to 28 tsi. As they are higher than previous estimates, these values support the residual-stress theory of failure. A theoretical investigation of the stresses in an idealised piston shows that cracking at the junction of the crown and skirt is caused by fatigue. Examination of four actual failed pistons confirms this finding.

Calculated stress curves are drawn, showing the variation of piston stresses with changing wall and crown thickness. The stresses due to combustion pressure are independent of the scale of the piston, but dependent on its proportions. This also applies to the thermal stresses, provided that the temperature distribution is the same. Since the piston temperatures increase with increasing size, the thermal stresses in large pistons are greater than in small pistons. The stresses produced by the combustion load are shown to be smallest when the crown and wall are thick. For low thermal stresses, a thin crown is necessary; for low thermal stresses in the wall, the wall should be thick, but a thick wall causes high thermal stresses in the crown.

An example has been worked out to show graphically the variation in the overall stress conditions at the inner edge of the wall and at the inside face of the crown centre, as the crown and wall thicknesses are varied. For the conditions assumed, the wall and crown should be approximately of equal thickness and one-tenth of the piston diameter. These figures include consideration of the compressive stresses in the hot face of the crown.

The conclusion is drawn that, where circumferential cracking has occurred in the wall, in the absence of cracks elsewhere, design changes should be directed at reducing the stresses at the position of failure, even though the stresses at other vital positions may be increased as a result. This requires the wall to be thickened, thereby raising the temperature of the upper ring; this tendency, however, would be counteracted by cutting suitable grooves in the piston wall.

Alternative designs are suggested which might be useful in overcoming cracking troubles in the pistons of large or highly rated engines.

IRON AND STEEL

Blistering and Embrittlement of Pressure-Vessel Steels by Hydrogen.

By G. A. NELSON and R. T. EFFINGER. (From *The Welding Journal, U.S.A.*, Vol. 34, No. 1, January 1955, pp. 12s-21s, 11 illustrations.)

HYDROGEN under certain conditions has the ability to diffuse through solid steel. Dissociated or atomic hydrogen can diffuse into, through, and out of the steel. The effects of hydrogen, while temporarily present in metals, have commanded the attention of many metallurgists, engineers, and other investigators, and it is expected that in the future the exact mechanism by which hydrogen travels through will be investigated further.

The authors of this paper do not attempt to evaluate all the theories that have been proposed to explain the mechanism by which hydrogen travels through steel, but attempt to use the most important gleanings from technical papers which are most applicable to designers, fabricators, and users of equipment required for many modern chemical processes.

Both the temporary and permanent detrimental effects of hydrogen in metals are discussed, including the effects of high-temperature, high-pressure hydrogen as met with in hydrogenation and reforming processes, and the effects of hydrogen in low-temperature plants where hydrogen is developed at the steel surface while being exposed to certain corrodents. The environment and the processes in which this high- and low-temperature hydrogen attack occurs are quite different, yet there are enough similarities to justify consideration of some phases in common and to point out the dissimilarities which must be taken into account in the construction of process plants.

The effects of hydrogen in both types of processes are described separately. Methods of protection against damage are also discussed. While the facts are not complete, the interpretation of the data may orient the problem and point the way towards further investigation.

Brittle Fracture of Steel.

By W. FELIX and T. GEIGER. (From *Schweizer Archiv, Switzerland*, Vol. 21, No. 2, February 1955, pp. 33-49, 33 illustrations.)

THE first part of this paper deals with investigations into the process of fracture in the notch impact test, with special reference to mild steel fractured in the low range of the notch impact strength. It was found with the aid of X-ray diffraction photographs that, in specimens fractured without any external deformation at extremely low notch impact figures, some of the crystals in the surface of fracture showed no detectable plastic deformation, while in other crystals fracture had taken place only after definite, though slight, plastic deformation.

The examination of the structure of specimens fractured with gradually increased impact energy further revealed that fracture is preceded by the brittle cracking or splitting of individual crystals. It is only after a further increase in stress that a microscopic

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"*I told the Guv'nor straight*," he said, "*— if you want this lot out on time, I want more up-to-date handling equipment!*"

We murmured admiration for his fearlessness . . . then we told him we were from Yale & Towne; we'd been called in by "the Guv'nor" to see how we could help.

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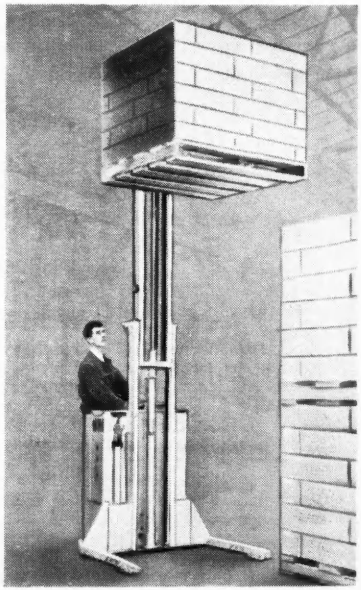

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P.3.

crack appears at the root of the notch, whereupon the intact regions between the disrupted crystals begin to give way, their crystals undergoing a measure of deformation in the process. The fractures which occur without apparent deformation in the low range of the impact energy must therefore be regarded as mixed fractures over microscopically small areas, since the crystals which undergo brittle fracture alternate with others whose cohesion is broken down only after some plastic deformation.

The second part of the paper deals with an H-girder which was destroyed in service by brittle fracture. The failure was attributed to marked brittleness of the steel. The X-ray and metallographic investigations of the crystals in the fractured surface showed that the crystals had once more undergone differing degrees of deformation. In particular, it was clear from the scatter of the micro-hardness figures that, while some of the crystals had been more or less seriously deformed, there were others which had suffered no apparent plastic deformation. It was also shown that the hardness in the undeformed state, and more especially the degree of cold working of the crystals in the surface of the fracture, depended to a large extent on their orientation. In a section at right angles to the fracture, the undeformed crystals were in positions chiefly neighbouring on the (100) plane, while the deformed crystals were near the (111) and (110) planes.

The similarity of the crystal conditions in the fractured surfaces of the notch impact specimens and the girder permits the conclusion that the service fracture obeyed the same laws as those governing the notch impact tests in the extremely low energy range, as described in the first part of the paper. It was shown in particular that the orientation of the crystals in relation to the direction of application of force is the deciding factor controlling the process of fracture.

The paper also serves to demonstrate that X-ray examination of the micro-structure and micro-hardness testing can furnish useful evidence for the diagnosis of the causes of fractures due to impacts.

JET PROPULSION

Characteristics of Free Supersonic Jets Exhausting into Quiescent Air.

By A. R. ANDERSON and F. R. JOHNS. (From *Jet Propulsion, U.S.A.*, Vol. 25, No. 1, January 1955, pp. 13-15, 25, 8 illustrations.)

MANY attempts have been made to develop a satisfactory theory for the mixing of a jet with quiescent air. Although significant contributions have been made by a number of investigators, these, however, deal almost entirely with low-speed incompressible flows.

The study described in this article was made to determine the radial spreading and axial decay of supersonic jets exhausting into quiescent air. Basic parameters were determined by using a supersonic, heated-air jet at exit Mach numbers of 1·40 and 1·84. To extend and correlate the heated-air testing into a higher Mach-number and temperature region, three different types of solid-propellant rockets were tested.

It is understandable that the decay in the supersonic region will be greatly complicated by shock and expansion-wave interactions, which in turn are functions of nozzle design, Reynolds number, etc. A satisfactory theoretical description of the flow in this region is practically impossible but, since the main interest in this particular instance centres around the flow conditions after decay to subsonic speeds, the premise is that below the sonic point the theoretical concepts involved in the available theories are again adequate and may suitably describe the flow.

From the results of these studies of free jets exhausting into quiescent air, data are available on axial decay curves of pressure, temperature, and velocity; on radial profiles; and on spreading characteristics. From the information obtained and the knowledge of rocket-exhaust characteristics, conditions downstream of any supersonic jet can be determined with sufficient accuracy for engineering purposes.

In addition, the following conclusions are drawn:—
(1) Radial profiles of pressure, temperature, and velocity can be non-dimensionalised. Free jet velocity profiles closely parallel the Prandtl momentum transfer curve, and free jet pressure and temperature profiles parallel the composite heated-air jet profiles. In the range of temperature investigated, temperature has a negligible effect on non-dimensional profiles.
(2) After the free supersonic jet decays to the sonic point, it can be treated as a normal shock-free parallel flow jet.
(3) Velocity decay beyond the supersonic core follows the axial-decay curve of Szablewski, regardless of the exit Mach number or exit temperature.

MATERIALS TESTING

The Instability of Testing Machines.

By A. H. CHILVER. (From an advance copy of a paper submitted to *The Institution of Mechanical Engineers, London*, February 1955, 10 pages, 15 illustrations.)

AN essential requirement of a testing machine is that the main frame of the machine should possess sufficient stiffness to provide complete structural stability for all types of test to be carried out. Complete stability is achieved in most tension-testing machines, because the main members of the frame—which are in compression—can be designed with the most elementary knowledge of strut stability. A tension machine usually possesses a more than adequate margin of "stiffness" to ensure complete structural stability for all working loads.

With compression-testing machines, in which the main members are in tension, there has been a tendency in the past to ignore even the possibility of buckling of the whole machine. This disregard of the instability problem is based on the plausible assumption that a main member of a compression machine is in no way prone to instability in the generally accepted sense. A closer inspection of the problem shows this argument to be untrue; indeed, it finally leads to the conclusion that the stability of a compression machine may be more difficult to ensure than that of a tension machine.

The main frame of a simple compression machine consists essentially of two rigid cross-members connected by a number of relatively flexible ties; the test specimen is compressed between the cross-members. The connecting ties are designed primarily to withstand the tension loads induced by the reactions from the compression specimen. The stability of the system as a whole is governed largely by the flexural stiffnesses of these connecting ties. The straining mechanism or loading unit of the machine is usually housed in one or other of the rigid cross-members. In laboratory work the testing of specimens with ball-ends or knife-edges is of frequent occurrence; a discussion of this mode of support represents a convenient point at which to begin a study of possible forms of instability.

In this paper, it is demonstrated that the buckling of a simple testing machine may be treated as an elementary problem in elastic stability. The case of a simple compression machine is first studied; it is found that machines of this type may be highly unstable if the length of a ball-ended compression specimen is short in relation to the length of the connecting ties. This adverse feature of compression machines is confirmed by general experience in compression testing. The theory of instability presented is in good agreement with the results of tests on both model and full-size compression-testing machines. With tension-testing machines, it is found that, for most practical conditions, the length of the tension specimen is not a critical factor.

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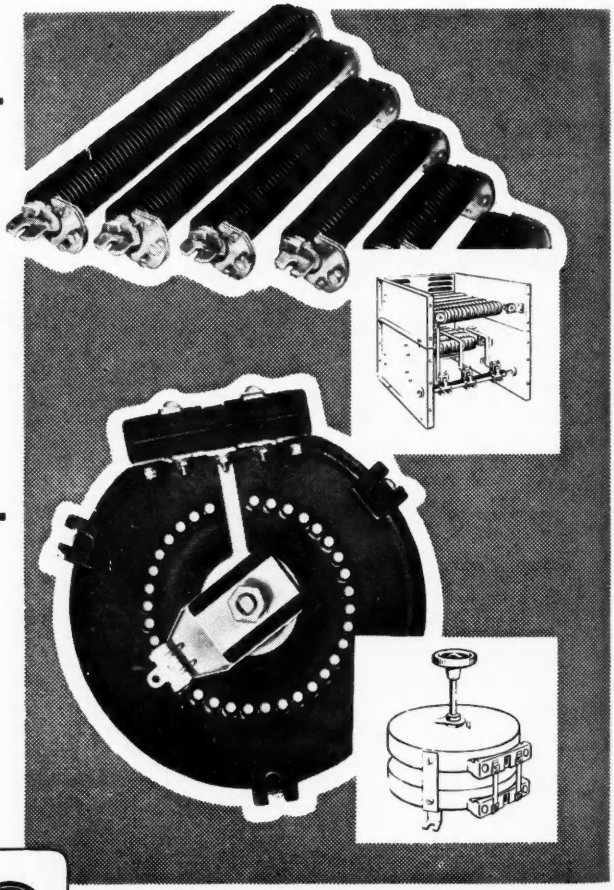

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METALLURGY

A Study of the Plastic Deformation of Copper Single Crystals.

By C. R. CUPP and B. CHALMERS. (From *Acta Metallurgica, U.S.A.*, Vol. 2, No. 6, November 1954, pp. 803-809, 13 illustrations.)

THE purpose of this paper is to present evidence of a yield phenomenon in single crystals of copper, and some observations on the effect of hydrogen on the mechanical properties of the crystals and on a transition in the stress-strain curve of copper crystals.

A type of yield phenomenon has been observed in single crystals of " super-pure " copper tested at room temperature. A new feature of the results obtained is that the yielding has been found to occur in a face-centered cubic material with less than 0·002% substitutional impurities present. It has been found that ageing for a few minutes *in situ* at 26° C, and under the maximum load to which the specimen had been subjected up to the time of ageing, is effective in producing yielding. Since a " soft " tensile machine was used, it was impossible to obtain a fall in load at the beginning of plastic deformation. However, the sudden yielding and subsequent rapid deformation were indicative of the presence of a yield point which could be obtained by suitable ageing treatment, and which was absent if ageing was not permitted.

It is interesting to note that some of the stress-strain curves resemble the stepped stress-strain curves found for various alloys. However, the stepped curves for the alloys were obtained by loading the specimens at a steady and quite rapid rate, while the present curves result from discontinuous and slow loading. In other work on alloys, discontinuous, but rapid, loading was used.

The dislocation-theory mechanism proposed by Cottrell to explain strain-ageing effects and yield phenomena accounts for the behaviour which has been observed here. A substantial solute should be able to cause a yield point which would be expected to be weaker than the well known yield point in the iron-carbon system. This is in agreement with the present observations.

The consistent effect of developing a higher rate of work-hardening and/or a higher critical resolved shear stress by annealing one of two identical crystals in hydrogen would suggest that this atom in solution affects the slip mechanism. However, the effects of minor crystalline sub-structures should be determined before it is definitely concluded that the hydrogen alone is responsible for the effect.

THERMODYNAMICS

The Present Status of Steam Properties.

By F. G. KEYES and J. H. KEENAN. (From *Mechanical Engineering, U.S.A.*, Vol. 77, No. 2, February 1955, pp. 127-132, 12 illustrations.)

THE Third International Steam Tables Conference, held in the United States in 1934, reviewed the reports of investigations of steam properties submitted by investigators from the United States, England, Germany, and Czechoslovakia. The reports considered were based upon some ten years of measurement effort commenced under the auspices of the ASME, following a meeting of scientists, engineers, and turbine designers in Cambridge, Mass., at Harvard University, in June, 1921. The result achieved by the third conference of 1934 was the definitive International Skeleton Steam Tables, accompanied by estimates of accuracy, or "tolerances," and included the designation of fundamental units, definitions, and conversion relationships.

In view of the considerable amount of new data and important correlations of experimental findings reported since the 1934 conference, the present status of the 1934 International Skeleton Tables data may be summarised as follows:—

(1) The accuracy of the data is established by the test of thermodynamic consistency, when the test is carried out employing the results of the recent experimental comparison of the international-scale temperature with the thermodynamic scale.
(2) The additional experimental data reported for water substance since 1934 indicate no trend which in any way reflects against the accuracy of the 1934 table. There is an exception, however, in the case of the 1950 Russian data, which extend beyond the 1934 superheat volumes in temperature and in pressure. Pressures computed, using the equation of state based on the Skeleton Tables superheat data, fail to agree with new Russian data, being smaller by about 1%.
(3) The need for additional experimental data extending beyond the range of the 1934 Skeleton Tables is urgent, not only for present design needs, but for turbine design suited to even higher pressures and temperatures. The higher limits proposed are 800° C and 1000 atm. With contemporary materials and the experience accumulated earlier, together with the 1934 data of proved accuracy as a base upon which to build, it is believed that these very high limits are attainable.
(4) The design treatment of heat-transfer equipment depends upon reasonably accurate data for viscosity and thermal conductivity. It is imperative that the present discordant array of transport quantities be disposed of through new research. Viscosity and thermal conductivity should be known at low pressures with an accuracy of at least 1% to 800° C, and to pressures of 200 atm to temperatures of 400° C. The pressure effect falls so rapidly with temperature increase that it need not be measured to 800° C.

There is scarcely need to remark upon the desirability of devising an international organisation to carry out the suggested programme. The happy outcome of the earlier venture in international co-operation is persuasive evidence that the next great advance in knowledge of water-substance properties may be even more significant than that which terminated with the 1934 conference.

A "LIQUID-VAPOUR" AUTOMATIC ELECTRIC MOTOR STARTER

(*Concluded from page* 100)

and sizes, as well as starting-up conditions; all that is required is to adjust the volume of the electrode chamber by inserting between the electrodes a small separator of appropriate thickness. Experiments have shown that with this method a starter can be used successfully for motors ranging from 10 to 100 hp and for the most varied starting-up conditions. In practice, however, it will usually be necessary to limit the capacity controlled by one starter to 40 hp and, in the case of larger motors, to use several starters connected in parallel, one for each 40 hp capacity. The possibility of building up starters from simple units to suit motors of different types and sizes, as well as operating conditions, would appear to be a very considerable step forward, as hitherto a very wide range of individual starters has had to be manufactured for this purpose.

A further advantage is the small size of the apparatus, particularly when compared with conventional types, inasmuch as it is only about 8 in. in diameter by 18 in. in height. In addition, there are no moving parts, and practically no maintenance is required. It is robust and its cost is only a fraction of that of other automatic starters, even comparing well with the cost of ordinary hand-operated types.

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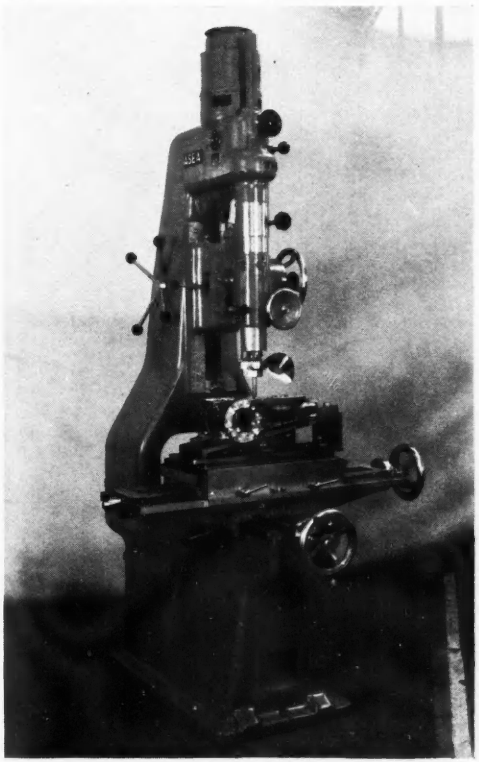
New Materials, Processes and Equipment

JIG-BORING MACHINES

Details of the new jig-boring machines, types SJ and SJB, manufactured by ASEA, of Stockholm, Sweden, are announced by their British agents, Mortimer Engineering Co., of Harlesden, London, N.W.10.

The frames of these machines are constructed of cast iron and are very strongly dimensioned. The frame serves as a support for the column and is fitted with a knee-shaped support for the table. Compartments for tools, etc. are also provided inside the frame. The column has amply dimensioned guides for the spindle head, and the vertical drive motor is mounted on top of the column, inside which the gear box, operated by a ball lever on the right-hand side, is located. The table is constructed of very hard, special cast iron and is provided with T-shaped slots, scraped parallel to the transverse feed of the table, with a tolerance of ± 0·01 mm. The table is locked by means of a single lever on type SJ and by two levers on type SJB.



The carefully scraped guides of the cross-slide are of the narrow-gauge type. The slide is set with the aid of micrometer screws and locked by ball levers on each side. The guides of the table and the cross-slide are protected against chips and dust by sheet-iron guards and felt chip brushes. The setting of the table and the cross-slide in both longitudinal and lateral directions is carried out according to a vernier scale with an accuracy of 0·1 mm, and by micrometer screws with calibrated scales. These screws, which are of 40 mm diameter and 4 mm pitch, are hardened and have carefully ground threads. The accuracy of pitch along the entire length of the screw is ± 0·01 mm on type SJ and ± 0·015 mm on type SJB. Accuracy on a length of 25 mm anywhere along the screw is ± 0·003 mm. The screw scales are calibrated in 0·01 mm, and readings can be taken with an accuracy of ± 0·005 mm.

The spindle is constructed of special steel and is milled as a four-spline shaft. The lower part is hardened and provided with a carefully ground holding taper for the tool. The two lower conical roller bearings are adjustable, to take up boring pressure. The upper bearing is of the ball-bearing type. The free part of the spindle is protected against dust, etc. by a telescopic tube, and both the spindle and its sleeve are balanced by counterweights. The boring depth is 100 mm on type SJ and 175 mm on type SJB.

The machine feed is located in the spindle head and provides for three feed speeds and rapid withdrawal. A hand-operated fine feed is provided, together with a change-over device for up and down feed, combined with a hand-operated release and an adjustable stop for automatic cut-out. Change from one feed to another is effected by means of a handwheel, without any need to stop the spindle.

FRICTION-MATERIALS TEST MACHINE

The design and development of new equipment, known as the Chase Friction-Materials Test Machine, for friction testing of materials under load, such as brake linings, embodying several new concepts in testing and machine design, is announced by the Link Engineering Company, of Detroit, Michigan. The design of the machine is based on the fact that, if a loaded sample of the material to be tested is held and made to ride on the rim of a revolving drum, at a point on the vertical centre line a horizontal friction force tangent to the drum surface will result.

Because this horizontal frictional force is approximately the same at all speeds, a variable-speed, constant-torque power unit must be used to power the drum through all speeds and loading conditions desirable to test the material. The revolving drum is located on the end of a shaft mounted in self-aligning ball bearings. Between these bearings is a flywheel driven by two V-belts from a variable-speed unit. Maximum speed of the shaft is slightly over 900 rpm.

One of the important features of the new machine is a restraining device with the ability to maintain position of the test sample on the vertical centre-line of the drum, regardless of any variation in the frictional force. This pressure-sensitive restraining device measures and makes a continuous record of the characteristics of the material when subjected to any desired condition of operation.

Another important feature is that the position of the loading unit is entirely controlled in the friction-force line of action by the recording unit itself. The loading unit is kept within the plane of rotation of the force by two ball-end links which are perpendicular to the line of force. This arrangement ensures that there are no losses to be considered which would affect the recorded friction force.

In operation, a test sample, 1 in. square, is held in a specially designed block, which is hinged at the centre of the testpiece in the plane of the revolving drum; this hinged block ensures uniform transverse distribution of pressure and also permits regular examination of

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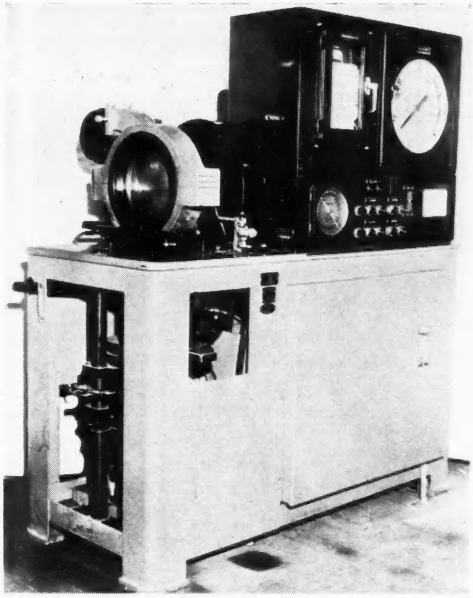


the test sample and easy replacement. Samples under test can be loaded in 25-lb increments up to 200 lb. For cycling the application and release of the load, an air cylinder with a solenoid-operated air valve is provided. Control of the cycling is handled electrically and is adjustable from intervals of ten seconds up to two minutes.

Since the heat resulting from the work done by such a small testpiece of friction material is not always sufficient to raise the temperature of the drum to that comparable in brake service, electric heating elements, with a capacity sufficient to raise the drum temperature well above the critical temperatures of most friction materials, are installed in a housing surrounding the drum. Thermocouples are located in the drum and lining, with current collector rings made of thermocouple materials on the drum hub, to provide for indication of the operating temperatures of drum and lining. Records of these temperatures are kept automatically. All controls, indicating, and recording instruments are located at heights most convenient for operation. Minimum air pressure required is 50 psi and the machine can be adapted with but minor changes for either 220 or 440 V a.c. current.

PARTICLE-SIZE DISTRIBUTION ANALYSER

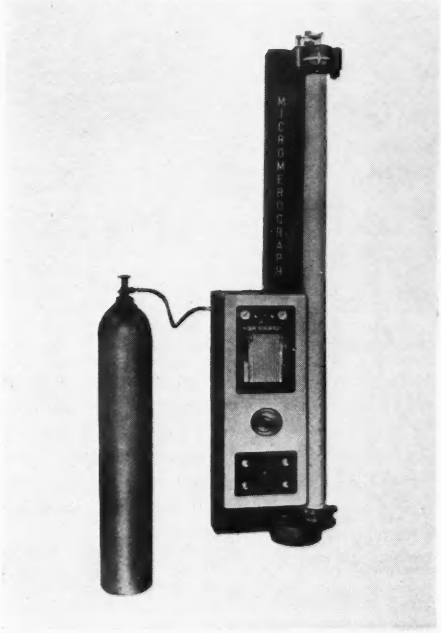
Manufactured in Philadelphia, Penn., and previously available for sale only within the U.S.A., the " Micromerograph " sets a new standard for accurate, rapid, and reproducible particle-size distribution analysis. Sharples Centrifuges Ltd., of Woodchester, Stroud, announce that the Sharples Micromerograph has now been made available for sale in the United Kingdom and Europe.

The Micromerograph is an automatic, self-recording, sedimentation balance type of instrument, with many outstanding features. Thus, for instance, it accomplishes determination of the particle-size distribution of a powder by projecting the powder sample through a de-agglomerator with a burst of compressed dry nitrogen. Nitrogen pressure and the orifice are adjusted for the particular material being analysed. The sample ejected from the de-agglomerator forms a small cloud near the top of the sedimentation column.

The particles fall at their terminal velocities until stopped by the pan of the servo-electronic balance at the bottom of the column. Slight differences in time of fall due to the finite size of the initial particle cloud are rendered unimportant by the relatively great length (220 cm) of the sedimentation column. The time required is from a few seconds to three hours, depending on the size distribution and density of the particles.

As the particles accumulate on the balance pan, a slight rotation of the balance beam on its torsion suspension occurs. A sensing device incorporated in the balance applies a signal to the electronic system of the instrument, which, in turn, applies a current to a restoring-force coil on the balance beam. The current required to keep the beam balanced is a continuous measure of the accumulated weight of powder on the balance pan.

The milliammeter of the moving-chart recorder is actuated by the same current that counterbalances the weight of the powder on the balance pan. The resulting chart is a record of accumulated weight against time. This chart is a continuous record, visually available throughout the determination. A determination is complete when the chart line becomes straight, although for many applications it is satisfactory to discontinue the run at an arbitrary time, at an arbitrary slope on the curve, or at some approximate percentage of total sedimentation. The information on the chart is used to obtain a complete particle-size distribution curve showing the percentage weight of particles smaller than any given micron size.



The Micromerograph is useful in production and quality control and as a research instrument. The statistical accuracy for routine testing is high, owing to the several billions of particles in the sample utilised (approximately 0·1 gr), and its operating range encompasses a very wide variety and size range of powders. The instrument is ideally suited for keeping the particle-size distribution of powders within safe or acceptable limits. Limits once having been established, non-technical operators can quickly check a size-distribution curve against a transparent overlay showing the area of acceptability. The Micromerograph chart and the

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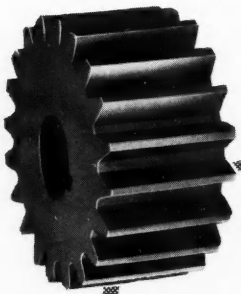

PEAK PINIONS are silent

For full technical details and illustrated applications please write direct to the address below.

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derived particle-size distribution curve form permanent records for future reference. Furthermore, the Micromerograph lends itself to any research or development programme involving the behaviour of powdered materials. The rapidity with which determinations can be made and the inherent dependability of the results allow the research programme to operate at many times the rate of progress possible with conventional particle-size methods. The application of the Micromerograph to problems involving penicillin for human use, tungsten carbide for cutting tools, and limestone for pigments, are but a few instances of its wide usefulness. In most research applications, the continuous data record of the Micromerograph is of outstanding value.

SUB-MACHINE GUN

Britain's latest weapon, the Sterling sub-machine gun, designed and manufactured by the Sterling Engineering Co. Ltd., of Dagenham, has been adopted by the British Army as a supplementary weapon to the Belgian F.N. rifle, replacing the Sten gun.

At the outbreak of World War II, the British Army had no weapon of this type and, in 1940, large numbers of Thompson sub-machine guns were obtained from America until the shortage was relieved by the production of the first Sten guns in 1941, designed to be produced rapidly and with a minimum of tooling. About the same time as the Sten was produced, the Sterling Engineering Co. produced their Lanchester machine carbine. This was modelled on the Pattern-1928 German Schmeisser, which, in its turn, had followed the original Bergman. The Lanchester was heavier than the Sten and was produced in large numbers for use by the Royal Navy.

In 1942, the Sterling Engineering Co. Ltd. started development of another weapon, the aim being to produce a lighter, handier, safer, and more reliable gun than any designed before.

The Sterling's " family tree," as illustrated above, is therefore as follows:—The Schmeisser (*a*), weighing 8½ lb, firing 500 rounds per minute, and accurate at 100/200 yards; the Lanchester (*b*), weighing 9½ lb, firing 550 rounds per minute, and accurate at 100/200 yards; an early Sterling gun (*c*) in the development stage, weighing 6½ lb, firing 550 rounds per minute, and accurate at 200 yards; and the Sterling (*d*), weighing 6 lb, firing up to 575 rounds per minute, and accurate at 200 yards.

The Sterling can be fired (with or without the bayonet and scabbard in position) from the hip, shoulder, or, in an emergency (with butt folded) with one hand, in pistol fashion, at a rate up to 575 rounds per minute. It is accurate and will kill at 200 yards, and will also kill at greater ranges, although no claim for complete accuracy is made beyond 200 yards. The muzzle velocity of the 9-mm bullet is 1280 fps.

The gun is so balanced that, when in the firing position with a full magazine, even when held by the pistol grip with one hand only, there is little tendency for the gun to tilt backwards or forwards. Even when firing a burst, this even balance is maintained. When not in use, the butt is folded under the weapon, as shown below, thus reducing the overall length by some 9 in. and increasing the general handiness. The weapon can, however, be effectively used with the butt folded. The forward part of the body, which provides a grip for the left hand, is perforated to assist cooling of the barrel. Even after prolonged firing, this part of the body remains quite cool. A guard is fitted near the front of the weapon, to prevent any possibility of the firer placing his finger too far forward. The length of the weapon with butt folded is 19 in. and with butt extended 28 in.

The design incorporates two safety features, as follows:—

(i) *Mechanical Safety*:—During the forward movement of the round from the magazine, the firing pin on the breech-block cannot come into line with the percussion cap of the cartridge until the round is actually in the chamber. This eliminates all possibility of a breech explosion.

(ii) *Applied Safety*:—The change lever has a " Safe " position, which locks the trigger and sear, irrespective of the position of the breech-block. Locking of the breech-block in the forward position eliminates the possibility of rounds being fired if the gun is dropped or shaken violently.

One of the principal features contributing to the reliability of the new gun is the self-cleaning action of the breech-block. The block has four spiral ribs machined out of its sides. These ribs have sharp edges and, as the block moves backwards and forwards inside the casing, they cut away any fouling, such as sand, dirt, or mud, and gradually drive it out of a specially designed slot below the barrel face and other apertures in the case. This action ensures that the breech-block way is kept clear and that the gun will continue to function efficiently under the worst active-service conditions.

The rear peep-sight is readily changed from 100 yards to 200 yards setting by a flip lever. The sight apertures are of different diameters—a 0·15-in. aperture for the closer ranges, where a wide arc of vision is essential, and a smaller aperture for the longer range, to assist in taking a more precise aim. Seven sizes of foresight blade are available.

The magazine holds 34 rounds and has a roller-type platform. It operates on the double-column feed principle and rounds are fed and fired from each column alternately. This eliminates the bottleneck occasioned by a single-column feed. The magazine is loaded by hand and does not need a filler or loader.

Other notable features of the new weapon include the ease with which it can be stripped for cleaning, repair, or replacement of components and its unimpaired performance under extreme service conditions, including icing-up, sand, and even mud.

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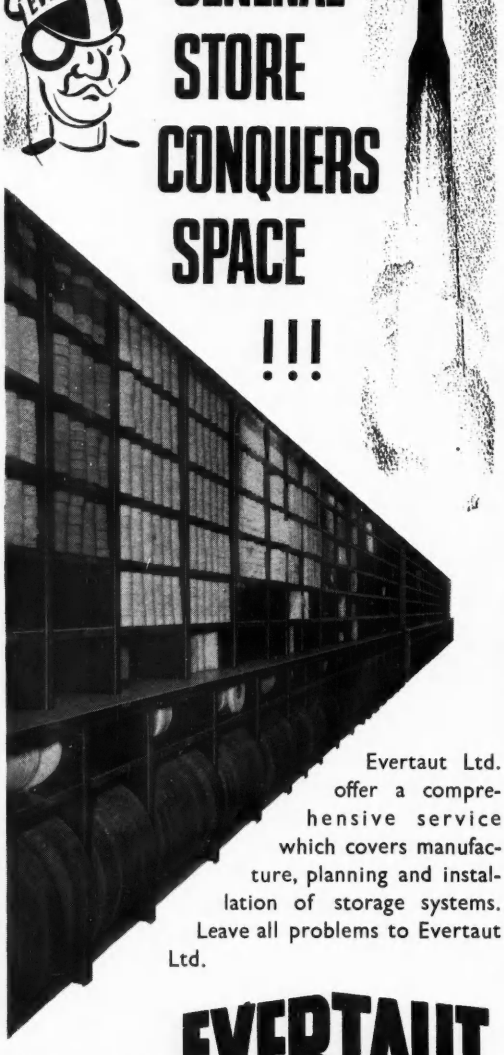

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Leaflet No. L.544 describing these Small Hole Gauges can be obtained from the address below, mentioning this journal.

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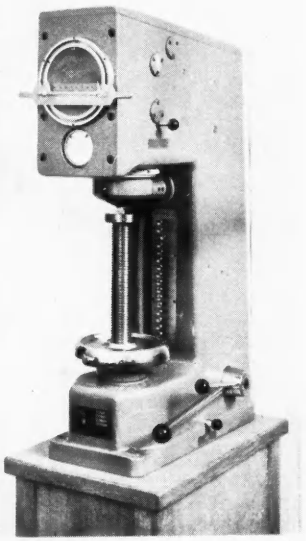
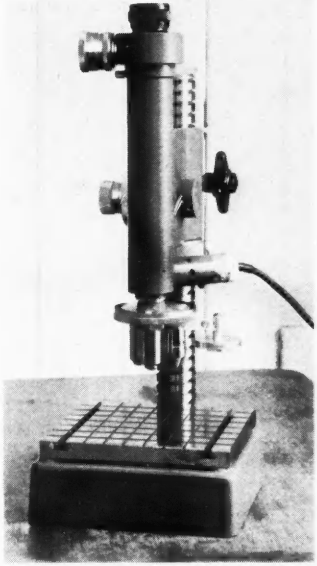
HARDNESS-TESTING MACHINES

Two new hardness-testing machines, the " Frankoskop " universal hardness tester and the " Mikrotest " optical micro-hardness tester, are announced by Karl Frank GmbH, of Weinheim-Birkenau, Germany.

In the development of the " Frankoskop " machine, illustrated below on the left, a new method has been found of reducing the time of application of different test loads, by means of a series of push-buttons arranged on the front of the column, thereby permitting the necessary load to be rapidly preselected. The load is applied by discs in the head of the machine, while an adjustable oil brake limits the speed of load application. The anvil carrying the sample is mounted on a robust screw spindle adjustable by a large handwheel. As shown in the illustration, the precision dial gauge (with automatic zero adjustment) for carrying out Rockwell tests is located in the head of the machine, and above the gauge is mounted the large screen for measuring the size of the indentation (Brinell-ball, Vickers, Knoop pyramid, or double-cone after Grodzinski). The machine incorporates a new and powerful optical system, in which the objective can easily be brought into the position originally occupied by the indenter. Precision guides and bearings ensure that the enlarged image of the indentation always appears in the field of view. Three different degrees of magnification ($\times 140$, $\times 70$, and $\times 20$) are provided, according to the size of the indentation, while the scales for the measurement of the indentation are so divided that, for the magnification chosen, they give the indentation length or diagonal directly in microns. Illumination is by means of a low-voltage projection lamp.



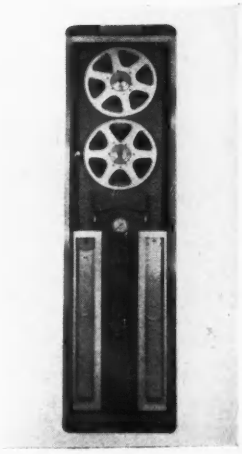


The " Mikrotest " optical micro-hardness tester, shown above on the right, is constructed for a load range between 50 and 500 grams in steps of 50 grams. Basically, the instrument comprises a microscope tube and a stand, to which is fitted a turret with two objectives, the indenter itself occupying the position of a third objective. A single lever, supported on a knife edge, butts against a member carrying the diamond indenter at its lower end, whilst the outer end of the lever carries the load discs. Accurate centering and frictionless power transmission are ensured. If required, the micro-hardness tester can be fitted to an existing microscope. The objectives ($\times 40$ and $\times 20$) are located in a precision indexing mounting, and remain well centered. The eyepiece is connected with a screw micrometer, one division of the knurled head of which provides a coarse adjustment of 0·1 mm and a fine adjustment of 0·001 mm with the $\times 20$ objective, or half these values with the $\times 40$ objective. Both coarse and fine adjustments are provided for the microscope tube itself. Illumination is provided by a 6V, 5W lamp.

MAGNETIC-TAPE TRANSPORT UNIT

Designed for use with most digital computer and data-processing systems, the magnetic-tape transport unit announced by ElectroData Corporation, of Pasadena, California, has a capacity of 2400 feet of $\frac{1}{2}$- or $\frac{3}{4}$-in. magnetic tape, which is moved at optional speeds of 30, 40, 50, 60, or 75 inches per second by two constant-speed capstan motors. Provision is made for the installation of two recording-reading heads, either of which can be selected remotely by mechanical control of the tape engagement. Using a standard $\frac{3}{4}$-in. tape and Brush series BK1500N or BK1300N heads, a maximum of 18 information channels is available.

Tape movement is controlled by two pinch-roller assemblies, each of which is controlled by a high-speed moving-coil actuator. Pinch rollers move five to six thousandths of an inch to press the tape against the capstan shafts. Both directions of tape drive are accurately controlled, to prevent accumulation of the tape in either of the vacuum columns adjacent to the reading and writing heads. Each is driven by a 1/20-hp d.c. motor through a reduction gear. Vacuum switches vary the speed of the motors to ensure proper tape feed under all conditions.



An outstanding feature of the unit is high-speed starting and stopping of the tape feed, accomplished by means of a vacuum-column control unit. Tape can be brought to a full stop, or to full speed in the opposite direction, in five to six milliseconds. Vacuum-switch control provides positive-stop action at either end of the tape. Tape feed is strain-free during operation. Switches are provided for local control of the unit, and remote control can also be accomplished by means of a remote-control terminal strip located on the chassis of the power supply.

By virtue of its remote-control features, this unit will perform, with associated control, such functions as search, selective reading and writing, rapid reversal of tape direction, rewind, and stop.

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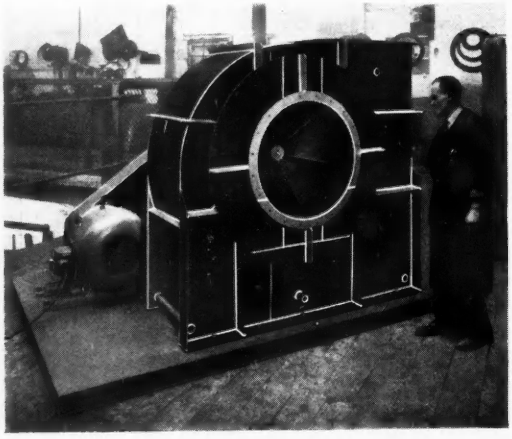

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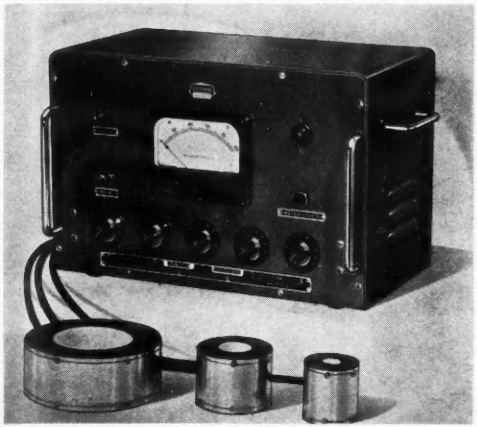
ELECTRONIC STANDARDISER FOR FERROUS METALS

An instrument which provides a simple and rapid method of testing small production samples and components of ferrous metals for metallurgical uniformity, as compared with a known standard sample or component, has been developed and produced by Excel Sound Services Ltd., of Bradford, Yorks. Known as the "Celsonic" Electronic Standardiser, Type E.S.2, the instrument detects differences in magnetic permeability between the standard and the material under test, and does not damage or mark the material in any way. As a result, 100% batch testing is possible, the rejected material then being subjected to the usual laboratory examination to determine the cause of rejection.



Once the Standardiser has been set up, it is possible for an unskilled operator to reject rapidly any material which falls below the required standard, either in respect of faults or differences in composition, or incorrect heat treatment. The degrees of departure from standard are clearly indicated on a meter, for which internal illumination is provided for use in badly lit locations. Components to be tested are placed in a suitable test head connected to the instrument, three standard test heads, with capacities of $\frac{3}{4}$, $1\frac{1}{2}$, and 4 in. respectively, being supplied. These heads will cover the majority of small components or samples normally encountered, but for certain types, e.g., those punched from sheet or plate, specially constructed test heads can be supplied, thereby ensuring that the instrument operates at maximum sensitivity. In addition, the instrument can be arranged for the continuous monitoring of quality during production, any variation in quality and section being instantly indicated on the meter.

LEVEL CONTROLLER

A new level controller, known as the "Pneutronic," combining electronic and pneumatic technique, is announced by Fielden Electronics Ltd., of Wythenshawe, Manchester.

From the electrical point of view, the new device is similar to the well known Fielden "Tektor" level controller, but the relay normally fitted is replaced in the pneumatic version by a novel converter which provides a proportional air output for the operation of a pneumatic control valve. A feedback loop into the capacity circuit ensures stability and provides bandwidth control. A slight modification of the electrical circuit provides a throttling action, instead of on/off operation, the resultant unit being a level controller with variable set point and variable proportional band width.

The controller will find its main application for liquids, though it is, of course, suitable for any system in which regulation is achieved pneumatically, as, for instance, with some powders and granular materials. It will be available with the range of probes and different housings already supplied for the standard "Tektor" unit, and possesses the inherent advantages of all Fielden level-indication and control devices, i.e., absence of moving parts in the container, and simplicity and reliability combined with accuracy.

ARC-WELDING TRANSFORMER

The latest addition to the range of air-cooled arc-welding plant manufactured by Philips Electrical Limited, of London, W.C.2, is their transformer, model ES1382, specifically designed as a machine for production work. With an output range of 60 to 350A, the plant has an electrode capacity of 12 s.w.g. to $\frac{5}{16}$-in. diameter. It is therefore suitable for production work on light, medium, and heavy fabrication, and for general maintenance and repairs.

One of the main features is that the welding current is infinitely variable throughout the range. Exact current settings, essential for high-quality work, can therefore be obtained. Alternative mains connections in the ranges 200 to 240 or 400 to 440 V a.c. are provided, and the plant may be connected to single-phase supply or between two phases of a 3-phase system. No-load consumption of the plant is 300W. Power-factor correction can be obtained by installation of a 6-kVA capacitor on the primary side. An open-circuit voltage of 75 to 80 V is obtained. Adequate cooling is ensured and a red light is fitted to indicate that the transformer is working. Compact and robust in design, the manœuvrability of the plant, which is mounted on three wheels, is increased by castor setting of the single wheel.

BRITISH INDUSTRIAL DEVELOPMENTS

(*Concluded from page* 118)

one layer of P.V.C. and two layers of P.V.C.-coated terylene. The layers are then bonded together, under carefully controlled conditions of heat and pressure, to give a light-weight, smooth-bore flexible hose.

As a guide to its potentialities, the following data are given for the $1\frac{1}{2}$-in. i.d. hose:—

Weight per foot 0·87 lb; bend radius 4 in.; elongation $\frac{3}{8}$ in./ft at 200 psi; test pressure 200 psi.

The second type is an unsupported collapsible, ultra-light, H.T.P. hose which can be wound on a reel, bearing in mind that the hose, even in its collapsed state, must not trap small quantities of H.T.P. and allow them to decompose. This difficulty has been overcome by producing a sandwich-type hose, made up of a layer of specially compounded P.V.C. between two layers of P.V.C.-coated terylene. During manufacture, a spiral channel is formed in the bore lining, and this rifling prevents the build-up of gaseous products, as, no matter how the hose is kinked, an escape passage is always provided along the entire length.

The figures for this $1\frac{1}{2}$-in. i.d. hose are:—

Weight 0·25 lb/ft; elongation $\frac{1}{4}$ in./ft at 150 psi; test pressure 150 psi.

In addition, a wire-supported and braided high-pressure hose is being developed. This consists of a medium-pressure hose with an additional overall braiding of stainless steel. The bend radius is actually improved by the addition of the braiding and the flexibility is claimed to be virtually unimpaired. The weight has been kept as low as possible. A $\frac{3}{4}$-in. i.d. hose, the first of the high-pressure range to be developed, is intended to have a working pressure of 800 psi.

SCREWS, NUTS & BOLTS

FONTANA, VEDUGGIO, MILAN, ITALY

NEWS OF THE MONTH

PERSONAL

Mr. W. D. Akester has been appointed sales director of Ransomes Sims & Jefferies Ltd., Orwell Works, Ipswich, with responsibility for co-ordination of home and export sales. **Mr. J. S. Canning** has been appointed home sales manager.

Mr. R. B. W. Bolland has been appointed a director of Head Wrightson Aluminium Ltd., Thornaby-on-Tees. Mr. Bolland is retaining his position of general manager of the company.

Mr. D. Colbridge has been appointed chief methods engineer of A.P.V.—Paramount Ltd., Crawley.

Mr. W. J. T. Dimmock, A.M.I.Prod.E., has been elected to the Board and has been appointed general manager of Hoover (Washing Machines) Ltd., Merthyr Tydfil. He succeeds **Mr. A. R. Northover,** who has resigned from the Board of the company.

Mr. R. M. Fairfield, B.Sc.(Eng.), M.I.E.E., M.I.Mech.E., M.Amer.I.E.E., has recently joined the Board of British Insulated Callender's Cables Ltd., 21 Bloomsbury Street, London, W.C.1, as director of production and engineering. Mr. Fairfield has relinquished his position of general manager of W. T. Glover & Co. Ltd., Manchester, and British Insulated Callender's (Submarine Cables) Ltd., but continues as director of these two companies.

Mr. W. V. Foley and **Mr. L. J. Tolley** have been elected to the Board of Renold & Coventry Chain Co. Ltd., Didsbury, Manchester.

Air Marshal Sir Victor Goddard, K.C.B., C.B.E., has joined Elliott Brothers (London) Ltd., Century Works, London, S.E.13, as an assistant (Air) to the managing director of the Company.

Sir John Green has joined the Board of Thos. Firth and John Brown Ltd., Sheffield, and has been elected chairman of the company. **Dr. C. Sykes** has been elected deputy chairman, in addition to his office as managing director.

Mr. R. H. Gummer, M.I.Mar.E., M.Amer.I.N.A., F.Inst.F., a director of International Combustion Ltd., 19 Woburn Place, London, W.C.1, and their associated companies, has been elected President of The Institute of Fuel, 18 Devonshire Street, London, W.1.

Mr. B. J. Haill, general works manager of the Brynmawr factory, has been appointed general works manager of the Cambridge Street factory, Manchester, of Dunlop Ltd.

Mr. R. Hope has been appointed Scottish area representative of Newall Group Sales Ltd., Peterborough, with headquarters in Falkirk.

Captain A. R. Mangnall, chairman and managing director of the Hydraulic Engineering Co. Ltd., Chester, has joined the Boards of General Hydraulic Power Co. Ltd., Hatfield Insurance Co. Ltd., Hypower Ltd., the Liverpool Hydraulic Power Co. Ltd., and the London Hydraulic Power Co. Ltd.

Mr. A. H. Mason, M.I.Prod.E., has been appointed technical manager of B.S.A. Tools Ltd., Mackadown Lane, Kitts Green, Birmingham 33. **Mr. V. R. Winrow, M.I.Prod.E.,** has been appointed chief draughtsman. **Mr. G. C. J. Legg, A.M.I.Mech.E., M.I.Prod.E.,** has been appointed deputy general manager of the Cardiff Division of B.S.A. Tools Ltd.

Mr. F. R. Mason has been appointed general manager of Metropolitan-Vickers Electrical Export Co. Ltd., 1/3 St. Pauls Churchyard, London, E.C.4, and **Mr. G. H. Jolley** has succeeded him as the company's principal representative at Trafford Park, Manchester.

Mr. K. J. Proctor, of 11 Woodburn Road, Northenden, Manchester, has been appointed to represent Sanderson Brothers & Newbould Ltd., Sheffield, in Lancashire, Cheshire, North Wales and Westmoreland.

Mr. Douglas Ramsden has been appointed director and secretary of Villiers Australia Pty. Ltd., Ballaarat, Australia, a subsidiary company of Villiers Engineering Co. Ltd., Wolverhampton.

Mr. S. Roberts, deputy managing director of Hoover Ltd., Perivale, Greenford, Middlesex, has been appointed managing director of the company, in succession to **Mr. J. A. Wykes** who has retired on account of ill health.

Mr. R. H. Steeds has been appointed regional manager for Scotland, of British Insulated Callender's Cables Ltd. He will work from the Glasgow office of the Company.

Mr. H. E. Tickner, A.M.I.Prod.E., A.M.I.I.A., formerly in charge of the paper cable factory, has been appointed works manager (Cables) in charge of all three cable making works of Enfield Cables Ltd., Victoria House, Southampton Row, London, W.C.1. **Mr. W. G. Turner,** who was in charge of the Blaenavon factory, the production of which has been transferred to Brimsdown, has been appointed manager of the covered wires department at Brimsdown. **Mr. R. A. Kirby, A.I.R.I.,** works manager, is taking up appointment with the subsidiary company, Enfield Cables (Australia) Pty. Ltd. in Sydney, Australia.

Mr. E. S. Waddington, F.S.E., A.M.(s.a.)I.Mech.E., M.Inst.W., Assoc.I.E.E., Assoc.(s.a.)I.E.E., of the Industrial Division of Philips Electrical Ltd., Century House, Shaftesbury Avenue, London, W.C.2, has been elected chairman of the Finance Committee of the Society of Engineers.

Mr. W. P. Warren, A.M.I.E.E., has been appointed general manager of Cantie Switches Ltd., Bromborough, near Chester.

Mr. G. T. W. Whitehead, O.B.E., M.I.Mech.E., has been appointed general manager (works) of Johnson & Phillips Ltd., Charlton, London, S.E.7.

Captain(E) E. A. G. Whittle, R.N., and **Mr. J. H. Pitchford, M.A., M.I.Mech.E.,** managing director of Ricardo & Co. Engineers (1927) Ltd., have been elected to the Board of Power Jets (Research & Development) Ltd. **Captain(E) E. J. H. Kirby, D.S.C., R.N.,** has resigned from the Board, due to Admiralty duties, and **Rear-Admiral W. G. Cowland, C.B.,** has resigned due to pressure of other work.

Mr. C. Wilson has been appointed deputy general manager of the Machine Tool Trades Association, Victoria House, Southampton Row, London, W.C.1.

Sir James Reid Young has been elected a director of Borg-Warner Ltd., Letchworth, Herts.

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For building-up worn or wrongly machined parts the 'Brailey' Process of electro-deposition of heavy nickel is indeed a "putting-on tool" without equal. There is no heating or distortion of the component and you can save worn or wrongly machined parts from the scrap-heap. Hundreds of firms use the Brailey Process which is approved by all Government Departments and other authorities.

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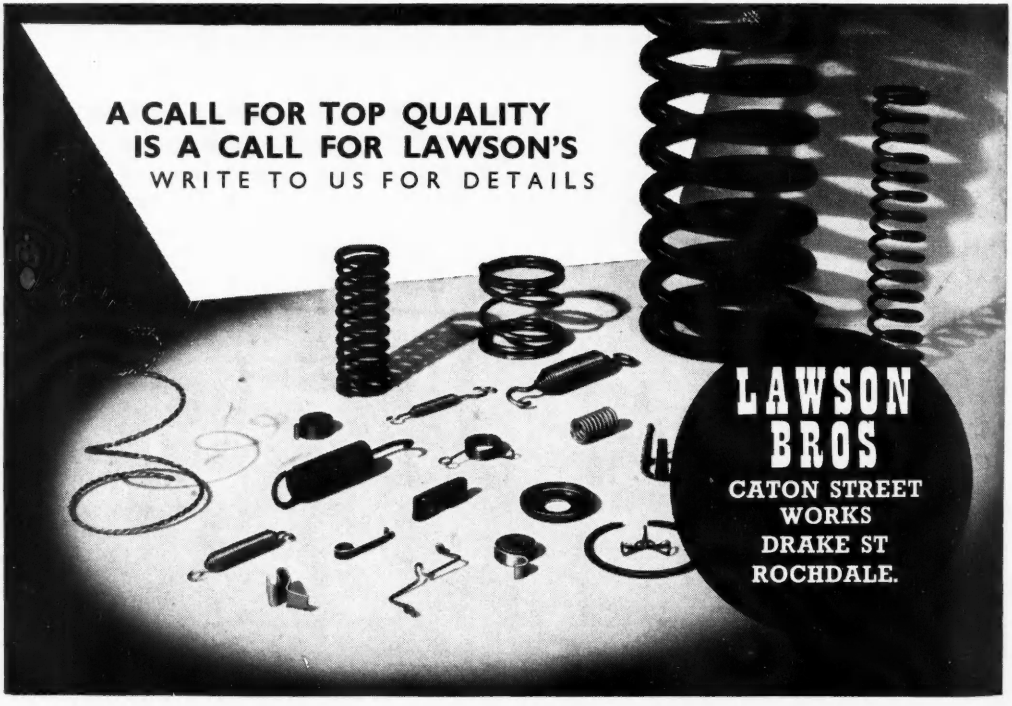

C.W. 2455

THE BRONZE AND BRASS CASTING INDUSTRY

Brassfounding is the oldest section of the foundry industry, with a history going back at least 4,000 years. It is, however, only during this century and principally since the war that practices within the brassfoundry have undergone marked changes. Until the new methods came to be adopted, foundry work, and in particular moulding, had been essentially the province of the craftsman. So that, understandably (as in other traditional craft industries) there has been reluctance to re-scheme work hitherto performed by a skilled technician so that it can be executed by a semi-skilled or unskilled operative. This reluctance has been due not only to pride in his work on the part of the individual foundryman but also to the fact that the industry as a whole has no large capital resources at its disposal.

While new methods have not been widely adopted, a number of technological processes have been developed since the war. Some of them, together with recommendations for raising the efficiency of the industry on a broader scale, are described in a Review of the Bronze and Brass Casting Industry published by the British Productivity Council, 21 Tothill Street, London, S.W.1, and available at the price of 2s. 3d.

The adoption of shell moulding, aluminium-alloy match-plates and the flexible and reinforced abrasive wheel are among the developments referred to. Stress is laid, however, on the necessity for the wider adoption of such general techniques as job simplification—which would leave the moulder free to concentrate on moulding instead of doing a wide variety of jobs; mechanisation—even to the extent of a few yards of roller conveyor; work study; and the adoption of a suitable costing system. The Review also urges the desirability of making foundries less unsightly than some of them are at present and also of ensuring that the prospects offered by the industry are more widely known among school-leavers.

The Appendix to the Review contains a series of case histories of both jobbing and specialist foundries of all sizes in various parts of the country. The steps that have been taken by these firms to increase their efficiency vary to a considerable extent. Some attribute their advance to the adoption of new technical processes, some to new layouts and some to mechanisation, while others again attribute it to the introduction of bonus incentive schemes or the use of work study.

Much remains to be done to win fuller acceptance for new foundry practices, and the Review urges greater co-operative action—in particular that firms which have not hitherto been members of the industry's trade and research associations should join them.

CONFERENCE ON COMPRESSED AIR

The Cornwall section of the Institution of Production Engineers is holding a two-day conference on "Compressed Air as an Aid to Improved Productivity" on 13th and 14th April, 1955, at the Cornwall Technical College, Trevenson, near Camborne, by permission of the Governors. Sir Walter Puckey, President of the Institution, will open the Conference.

Lectures will be held on the following subjects:—

"Compressed Air and its Compression," by J. R. Quertier, B.Sc., A.C.G.I., A.F.R.Ae.S., hon. technical director of the British Compressed Air Society.

"Pneumatic Tools, their Air Supply and Maintenance," by F. B. Coombes, A.M.I.Prod.E., chief designer of Holman Bros. Ltd.

"Air Operated Equipment," by W. G. Bennett, B.Sc., M.I.Prod.E., manager of Climax Rock Drill & Engineering Co, Ltd.

"A User's Experience," by W. E. Wright, chief planning engineer of the Engine Production Factory, Bristol Aeroplane Co. Ltd.

Mr. A. T. Holman, O.B.E., J.P., M.I.Mech.E., M.I.Prod.E., F.R.S.A., chairman and managing director of Holman Bros. Ltd., will be summing up the Conference., the programme of which will include works visits and demonstration of pneumatic equipment at Climax Rock Drill & Engineering Co. Ltd. and Holman Bros. Ltd.

Application forms may be obtained from the Institute of Production Engineers, 10 Chesterfield Street, London, W.1, or from Mr. F. G. Hawke, A.M.I.Prod.E., A.M.S.I.E., section hon. secretary, 17 Church Road, Pool, Redruth, Cornwall.

GERMAN WELDING CONFERENCE

The Annual Conference of the German Welding Society (Deutscher Verband für Schweisstechnik EV., Harkortstrasse 27, Düsseldorf) will be held from June 13th to 16th in Frankfurt/Main. The programme of the conference includes numerous lectures on the various aspects of welding progress by well-known German experts.

G.E.C. TO EQUIP NEW TRACTION WORKS

To augment its manufacturing facilities for electric traction, The General Electric Co. Ltd. has purchased a works at Dudley Port, Staffs., which will be devoted exclusively to the manufacture of motors, generators and auxiliary machines for electric and diesel-electric locomotives and rolling stock. The new premises will provide an additional 100,000 sq ft of factory space, and enable the Company to play its full part in meeting the big demand which must arise from the important development of British Railways programmed for the next 12 years.

The new works is situated within easy reach of the Company's Engineering Works at Witton, Birmingham, from which it will be controlled. It will form a self-contained manufacturing unit handling all processes from the raw material stage to the final assembly, testing and despatch of the machines. Flow-line methods representing the most up-to-date production practice will be adopted, and the works, which will be in full production within 12 months, will have a potential output of over £1,000,000 of equipment per year.

ARGONAUT WELDING PROCESS FILM

In the new British Oxygen Co. Ltd. colour film "The Argonaut Welding Process," the basic differences between this, the latest of the argon welding processes, and Argonarc are compared and clearly explained, and it is shown that the Argonaut process is a logical development of the earlier Argonarc process.

The manner in which a thin consumable electrode is used in conjunction with a high-density arc to give continuous, all-position welding is illustrated by animated diagrams and by high-speed photography, in which the action is slowed down 125 times. These slow-motion sequences, in which the characteristics of the arc and droplet metal transfer can be clearly seen, and others showing a comparison of the use of argon and nitrogen as shielding gases, are particularly effective. In addition, examples of the process in use on aluminium, stainless steel, copper, and mild steel are depicted, together with an impressive indication of the sections of metal on which the process can be used to advantage.

This film (16-mm, Kodachrome, sound, running time 26 min) will be available on loan to interested organisations.

G.E.C. ATOMIC ENERGY PLANS

The General Electric Co. Ltd. announces that Mr. R. N. Millar, lately chief mechanical engineer to The British General Electric Co. (Pty.) Ltd., Australia, has been appointed to take charge of its newly formed Industrial Atomic Energy Section.

The new organisation is located at the company's Erith works which is under the direction of Mr. Arnold Lindley. It will develop designs of plant for the utilisation of atomic energy in power station generating equipment, and it is the intention of The General Electric Co. Ltd. to provide most of the equipment for atomic power stations from within its own manufacturing organisation.

NEW E.D.A. INDUSTRIAL FILM

Expertly produced, directed, and photographed, The British Electrical Development Association's new industrial film, "Planned for the Purpose," illustrates the immense contribution that modern industrial engineering can make in the drive towards increased productivity. A basic "story" is well combined with diagrams, excellent model layouts, and shots of actual production stages in the plants of well known British companies, combining to pinpoint the vital factors involved in the effective planning of industrial equipment.

This interesting film, which runs for some 43 minutes, covers various aspects of the subject, including the planning of new projects, plant siting, plant layout, building design, and lighting, together with graphic details of various industrial techniques, such as mass, batch, and unit production. Not the least interesting feature of this production, incidentally, is the fascinating glimpse it affords of an industrial Utopia where, as a result of proper planning, pro-

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duction is not only stepped up to astronomical heights, but, *mirabile dictu*, sales and technical executives ungrudgingly attribute their success to the other's efforts.

This is the second film to be produced by E.D.A. on the subject of electricity and industrial productivity, the first being the 32-minute production "A Case for Handling," dealing with modern methods of materials handling in various types of Industrial plant. Both these productions (sound, 16 or 35 mm), as well as others from their film library, are available on free loan on application to the Association, at 2 Savoy Hill, London, W.C.2.

BRITISH AIRLINERS FOR COLOMBIA

A Colombian airline operating from Bogota in South America, Lloyd Aero Colombiana, has ordered a number of Handley Page *Herald*, airliners. When the *Heralds* are delivered, they will be the first British airliners to go into service in Colombia, where American-built transport planes have in the past formed the equipment of the major operators.

This order—the second to be announced for *Heralds* in two weeks—brings the order-book for the new transport to 29 planes. Last week it was disclosed that Australian National Airways had ordered a large fleet of *Heralds*.

The *Herald* is the first of two British aircraft designed to replace the *DC*-3 in the fleets of the world's airline companies. The second type will be the Aviation Traders Accountant which is to be powered by two Rolls-Royce *Dart* turboprop engines. The *Herald*, by contrast, has four piston engines, which give a shorter take-off run than is possible with turboprops; in fact, a grass runway only a thousand yards long is sufficient for *Herald* operations even at full payload.

The Handley Page airliner will be fully pressurized to provide maximum comfort for the passengers. Its ability to carry more than four and a half tons of freight as an alternative to passengers at the low figure of 1/3d a ton mile will be of great value in South America, a land of immense distances and inadequate surface communications, where air freight play a much bigger part in the continental exonomy than in other parts of the world.

Another British type, for executive or airline use, which has recently visited Colombia, is the de Havilland *Heron*. It too provides four-engined safety, and can carry up to seventeen passengers. Two South American countries, Brazil and Uruguay, already use *Herons* on airline services. The plane which visited Colombia is a demonstration machine flown by the maker's representative in South America, Group Captain A. MacDougall; it is the aircraft in which Princess Margaret flew from Nassau to Eleuthera Island, during her recent tour of the West Indies.

CAREERS IN THE ELECTRICAL INDUSTRY

More than 2,500 schools and technical colleges throughout the country have been sent a copy of a new booklet listing many scholarships and grants available in the electrical engineering industry. The booklet has been published by the British Electrical and Allied Manufacturer's Association "to illustrate the interest which the industry takes in education and research and the encouragement which is given to the student who wishes to widen his experience and knowledge."

Mr. D. D. Walker, Chairman of the Council of the B.E.A.M.A., in a foreword to the booklet, says: "The electrical and allied engineering industry is one of the most progressive in the country, and its importance in the national economy continues to increase. It is fully aware that a regular intake of well-trained and able recruits to fill the many responsible positions in the industry is necessary if expansion is to be maintained."

The booklet gives details of scholarships open to non-graduates, chiefly those leading to a first degree in electrical engineering; post-graduate scholarships and research awards open to senior students; and scholarships and awards permitting study abroad.

ELECTRONICS EXHIBITION

The Tenth Annual Exhibition organised by the Northern Division of the Institution of Electronics will be held at the College of Technology, Sackville St., Manchester, 1, during the period July 14th-20th, 1955. The Exhibition will be officially opened at 2.30 p.m. on Thursday, July 14th.

The Exhibition, which is organised for its educational value, will consist of a Manufacturer's Section, A Scientific and Industrial Research Section (including exhibits from the Hospitals, Research Associations, and Universities, etc.) and will include a Programme of Lectures and Film shows on subjects allied to Electronics. There will be exhibits of interest to members of all branches of Science and Industry.

Lecture and Film Show Programmes (post free 4½d.) will be available in June. Advance Catalogues (post free 2/-) will be on sale early in July.

Admission to the Exhibition, Lectures and Film Shows will be by tickets obtainable, free of charge, from the Honorary Exhibition Organising Secretary, Mr. W. Birtwistle, 78 Shaw Rd., Rochdale, Lancs., or from any of the Exhibitors. A stamped addressed envelope should be enclosed.

BUSINESS NOTES

B.M.B. (Sales) Ltd. have transferred their offices from 2 Balfour Place, Mount Street, London, W.1, to "Boscobel," High Street, Crawley, Sussex. Tel.: Crawley 1030, Telegrams: Briman, Crawley.

Alexander S. Newall Machine Tool Co. Ltd., 162-287 Finchley Road, London, N.W.3, have formed a new subsidiary company called Alexander S. Newall Machine Co. (Manchester) Ltd., at 304 Withington Road, Manchester 21, under the management of Mr. F. J. Higgins.

The Gauge and Tool Makers' Association, Standbrook House, 2/5 Old Bond Street, London, W.1, has published the sixth edition of the Association's Handbook. It includes, in addition to summarising the aims, objects and activities of the Association, a complete list of the 308 member-firms and a Buyer's Guide to their products. Copies are available free of charge.

Jenolite Ltd. have moved their offices to 13/17 Rathbone Street, London, W.1. Tel. No.: MUSeum 5411.

At the beginning of April the Sales Division of **The Aerograph Company Ltd.,** manufacturers of DeVilbiss Aerograph Spray Painting equipment, moves into new offices at 47 Holborn Viaduct, London, E.C.1.

The factory and head office remain at Lower Sydenham, but sales and technical enquiries will be exclusively handled at Holborn Viaduct.

The Banbury Works of Northern Aluminium Co. Ltd., is now carrying out a modernisation programme planned to increase the output of sheet and strip by several hundred tons annually. Extensive remodelling of the remelting facilities is already under way.

The modernised mills and melting room will incorporate the latest equipment designed to achieve high volume output, including a larger and more powerful hot mill capable of rolling ingots of over a ton in weight. Melting furnaces are being overhauled and modernised and improved re-heating equipment will also be built.

Kingston Control Systems Ltd., Empire Chambers, Richmond Road, Kingston-on-Thames, has recently been incorporated to design and supply automatic control and instrumentation systems.

Frederick C. Kane Ltd., Park Royal, London, N.W.10, has completed arrangements for the manufacture in this country of food processing machinery designed and produced by Chisholm Ryder Company Inc., of the U.S.A.

Goodenough Pumps Ltd., Twickenham, announce that arrangements have been made for its pumps to be manufactured in Canada by Godfrey Engineering Company Ltd., 480 Metropolitan Boulevard, Lachine, Montreal, 52.

E. and L. B. Pinkney (Marine) Ltd., Zetland Road, Middlesbrough, has taken over the production and marketing of "Feltham" marine engines and reversing gears formerly produced by Bruce and Holroyd Ltd., Feltham, Middlesex.

The London sales office of the flexible plastics division of **Dunlop Special Products Ltd.,** under Mr. S. J. Perry, sales manager, has moved to Allington House, 136-142 Victoria Street, London, S.W.1. Tel. No.: VICtoria 6868.

The English Electric Company Limited has opened a new Sub-office at Barclays Bank Chambers, 3 Trinity House Lane, Hull (Telephone No. 35533), to cover an area that corresponds to No. 6 Sub-Area of the Yorkshire Electricity Board. Mr. M. S. R. Thompson is in charge of this new office, and is responsible to Mr. W. Plumb, manager, Leeds Branch.

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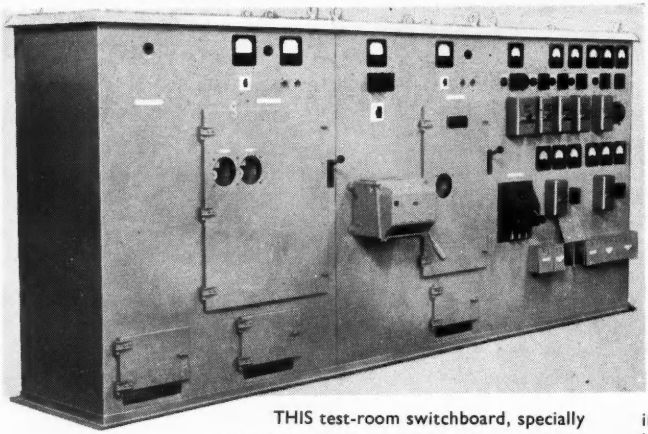

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ELECTROMAGNETICALLY ENRICHED ISOTOPES

A Conference will be held on the production and utilisation of electromagnetically enriched isotopes at the Atomic Energy Research Establishment from September 13th to 16th.

Leading U.S. scientists responsible for the work on stable isotopes at Oak Ridge are attending, and provisional acceptances have also been received from the heads of groups engaged on work with electromagnetic separators in France, Holland and Denmark.

Sessions will be held on the design and operation of large mass separators; ion sources and collector problems, especially those associated with high beam currents; the separation of radioactive materials; chemical aspects of work on isotope production; the preparation of isotopic targets; developments in the mass analysis of stable isotopes; and the utilisation of electromagnetically enriched isotopes.

Abstracts of papers must be submitted before April 30th, and complete manuscripts not later than June 30, in order that advance copies of accepted contributions may be available before the conference. Persons desirous of attending the meeting are asked to communicate with Dr. M. L. Smith, Atomic Energy Research Establishment, Harwell, Didcot, Berkshire, as soon as possible. They are also asked to state whether they will be prepared to contribute a paper.

SMALL FIRMS CONFERENCE

The third Small Firms Conference to be organised by the British Institute of Management, with the support of the Federation of British Industries and the National Union of Manufacturers, will be held at Harrogate on Friday and Saturday, April 29th and 30th.

CONTRACTS

British Insulated Callender's Cables Ltd. announce the receipt of a substantial order from the Electricity Commission of New South Wales, Australia. It is for the supply of 30,000 yards of high-voltage cable to form a double-circuit 8½ mile link between Bunnerong Power Station and the Canterbury substation in Sydney and it is expected that the cable will be in operation early next year.

The cable chosen is a 3-core 132,000-volt Impregnated Pressure cable which will be manufactured in England although its installation and maintenance will be carried out by an affiliated Australian company, British Insulated Callender's Cables (Australia) Pty. Ltd. The route is located in the Sydney metropolitan area, the cables having to run through heavily built-up districts, and includes a crossing of Cooks River.

The receipt of this contract follows closely on the successful completion last year of an order for the supply and installation of a 132kV Impregnated Pressure cable between the Rozelle and Homebush sub-stations in Sydney—the first 132kV cable to go into operation in Australia.

The British Thomson-Houston Co. has just received a contract valued at $11¼ million (£4·1m) for development and production of military electronic equipment for supply to NATO countries.

The contract has been negotiated with Hazeltine Electronics Corporation of New York City acting on behalf of the United States Navy Department.

The total value of U.S. Government orders now placed with BTH for military electronic equipment, including Fire Control Radar etc. amounts to $26m. (£9·2m). In addition, BTH has in the past five years supplied to European and Commonwealth countries direct £6 million worth of military radar apparatus.

International Combustion Ltd., 19 Woburn Place, London, W.C.1, announce that they have now received an order from the British Electricity Authority for three of the largest water-tube boilers in Europe, operating under the most advanced conditions of steam pressure and temperature in this country.

So far as is known this contract, the value of which approaches ten million pounds, is the largest single contract for boiler plant ever placed in this country and will provide work for some five to six years ahead.

Birwelco Ltd., Aston, Birmingham, announce the receipt of orders:

(1) From E. B. Badger & Sons Ltd., of Battersea, London, for the supply and erection of a Petro-Chem Iso-Flow furnace to be installed at the Grangemouth Works of British Petroleum Chemicals Ltd. This Petro-Chem Iso-Flow Heater is of Radiant Convection design and is developed from the first vertical heaters, designed by the American engineer de Florez, used in the oil refining industry in the United States.

(2) From Monsanto Chemicals Ltd., of Wilton Road, London, for the supply of three Petro-Chem Iso-Flow steam superheaters for installation at the Grangemouth plant of Forth Chemicals Ltd.

(3) From Tankage et Transport, S.A. of Antwerp, for the supply of a Radiant Type Petro-Chem Iso-Flow furnace for use as a charge heater in a U.O.P. platformer which is being engineered by Procon (Gt. Britain) Ltd., London.

Ferranti Ltd. has just received a contract valued at 4¼ million dollars for production of military electronic equipment for supply to N.A.T.O. countries. The contract has been negotiated with Hazeltine Electronics Corporation in New York City, acting on behalf of the United States Navy Department.

The Hydro-Electric Power Commission of Ontario has placed with the John Inglis Company of Toronto, Ontario, Canadian associates of The English Electric Company, an order for sixteen 75,000 hp fixed propeller type water turbines. The value of this contract amounts to seven and a half million dollars, and is one of the largest orders of its type ever to be placed with one concern. It comprises the complete turbine installation on the Canadian side of the much publicised St. Lawrence Water Power Project.

The equipment will be manufactured at the Company's Works in Toronto to the designs of the English Electric Co. Ltd.

The Power-Gas Corporation Limited of Stockton-on-Tees has recently been awarded a contract for the reconstruction of an existing sulphuric acid plant at the Flixborough Works of Nitrogen Fertilisers Ltd. The new equipment will be built to the designs of Chemiebau Dr. A. Zieren G.m.b.H., and will comprise a converter unit with a capacity of 140-tons per day of monohydrate, an acid separator, waste heat boiler and ancillary equipment.

The programme for installation of the equipment has been carefully planned to reduce to a minimum the inconvenience of shutting down the existing plant.

Head, Wrightson & Co. Ltd., Teesdale Ironworks, Thornaby-on-Tees, has received a contract from the British Transport Commission for 111 fifty-ton rail, sleeper and ballast wagons.

Richard Sutcliffe Ltd., Horbury, Wakefield, announce that they have been awarded a contract valued at nearly £500,000 for the complete mechanical plant for the Irlam development scheme of Lancashire Steel Corporation Ltd. It includes the supply of fifteen 36-in. wide belt conveyors, five plate feeders and ancillary belt trippers, crushers and junction houses, a wagon tippler, grizzly screens and cone crushers for the conveyance and treatment of iron ore, coal and coke.

Head Wrightson Machine Co. Ltd., Middlesbrough, contractors for the supply of continuous steel-strip galvanising equipment for the Ebbw Vale works of Richard Thomas and Baldwins Ltd., have now placed orders for the furnace and electrical equipment. Birlec Ltd. will supply the special processing furnace which will be divided into four sections, employing open-flame, radiant-tube and electric heating and will have the overall length of 180 feet. From the entry to the exit end of the line, the continuous strip travels a distance of 1,600 feet, and the electrical equipment, to be supplied by The English Electric Co. Ltd., is designed to give the very close control of line speed and tension which is essential when dealing with this length of light-gauge strip. A total of 75 electric motors are included in the equipment.

BRITISH STANDARDS

(Copies of British Standards may be obtained from the British Standards Institution, 2 Park Street, London, W.1)

Plain bearings (metal). Part 1: Dimensions of non-ferrous solid bushes and thrust washers. Part 2: Dimensions of wrapped bushes and thrust washers. Part 3: Dimensions of medium-walled and thick-walled bearing half-liners. Part 4: Dimensions of thin-walled bearing half-liners and thrust half-washers. Part 5: Bronze oil-retaining bushes and thrust washers. (B.S. 1131 : 1955).

Part 1 specifies the dimensions and tolerances for plain and flanged bushes, both those with a machining allowance in the bore and those which are pre-finished, and for thrust washers, for journals of ¼ in. to 5 in. nominal diameter. It specifies also methods of identifying the bushes and thrust washers and of marking the bushes.

Part 2 specifies the dimensions and tolerances for wrapped bushes, both those with a machining allowance in the bore and those which are pre-finished; and for thrust washers, for journals of ⅜ in. to 3 in. nominal diameter in inch sizes and of 10 mm to 58 mm nominal diameter in millimetre sizes. It specifies also methods of identifying the bushes and thrust washers and of marking the bushes.

Part 3 specifies the dimensions and tolerances of bearing half-liners for journals of 2 in. to 12 in. nominal diameter. There are two ranges of wall thicknesses and the half-liners may be:—

(a) in non-ferrous metal, unlined.
(b) in non-ferrous metal, lined with anti-friction metal.
(c) in ferrous metal, lined with anti-friction metal.

It specifies also methods of identifying and marking the half-liners.

Part 4 specifies the dimensions, tolerances and running clearances for:—

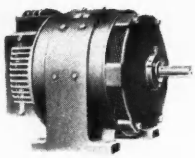
(a) steel-backed, thin-walled, grooved bearing half-liners for nominal journal diameters from 1 in. to 6 in.
(b) steel-backed, thin-walled, ungrooved bearing half-liners for nominal journal diameters from ⅜ in. to 6 in.
(c) steel-backed, thin-walled, thrust half-washers for nominal journal diameters from 1 in. to 6 in.

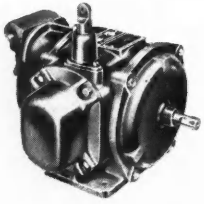
It specifies also methods of identifying the half-liners and thrust half-washers and of marking the half-liners.

Part 5 replaces B.S. 1131 : 1943 "Bronze oil-retaining bearings." It specifies the materials, dimensions, tolerances, characteristics and methods of identifying plain and flanged oil-retaining bushes and thrust washers, charged with lubricating oil and having a normal oil content of from 25 to 30 per cent by volume, within the size range from ⅛ in. to 2½ in. nominal bore. Price 4/– each and 7/6 for part 4.

Wrought Steels in the Form of Bars, Billets and Forgings. B.S. 970 : 1955 specifies requirements for wrought steels in the form of bars, billets and forgings up to 6 in. ruling section. It also sets out the chemical compositions of En steels which are normally supplied in the form of plate, sheet, strip and wire; for such products, however, reference should be made to: B.S. 1408: "Hard drawn steel wire for springs," B.S. 1429: "Annealed steel wire for oil hardened and tempered springs," B.S. 1449: "Steel plate, sheet and strip," B.S. 1554: "Rust, acid and heat resisting steel wire," B.S. 2056: "Rust, acid and heat resisting steel wire for springs."

To ensure the alignment of this series of standards, B.S. 1449 will shortly be issued in revised form and B.S. 1408 and B.S. 1429 have been amended.





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Ward (Metal Details) Ltd. specialise in the manufacture of all types of small and medium pressings. Illustrated here are but a few examples of the many shapes, sizes and thicknesses, in steel, tin plate, copper, etc. Complete assemblies can be fabricated from simple pressings by welding, soldering or brazing. Similar components can be produced from your designs and to your specification, and, if required, supplied in painted, plated or enamelled finishes.

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Also included are the case hardening steels of the En 350 and En 360 series which were issued as Emergency Specifications in 1951, but which have since become established as standard steels. Price: 12/6.

Methods for sheet metal pattern development. Part 2: Incidence of the neutral line. B.S. 1459 Pt. 2 : 1955 is a companion to Part 1 of this Standard, which was published in 1949. This part gives recommendations for the determination of the position of the neutral line for use with mild steel of from 14 to 20 B.G. and duralumin and half-hard aluminium of from 14 to 20 S.W.G., where the inside radius of the bend lies between a figure equal to the thickness of the metal and a figure equal to four times the thickness of the metal. Examples of calculations are given and supporting evidence is contained in appendices. Price: 5/-.

Drums for Covered Winding Wires and Strips. B.S. 2565 : 1955 gives full details of dimensions and specifies the essential requirements for materials, construction, reeling, wrapping, labelling and marking. It also introduces a system of reference numbers for the identification of the drums. A new feature is the specification of a peg hole in each drum to take a braking device. Price: 2/-.

Steel Roller Conveyors. B.S. 2567 : 1955 specifies important dimensions of the principal components of fixed and portable roller conveyors, within the range of maximum loading from 10 lb to 320 lb per roller. The standard does not apply to power-driven roller conveyors. Price: 2/6.

Control Chart Technique. B.S. 2564 : 1955 gives practical guidance on the use of Quality Control in all processes of manufacturing to a specification. Written by Dr. B. P. Dudding and Mr W. J. Jennett, it was first published by the General Electric Co. in 1944, and with the kind permission of the director of the Research Laboratories of the G.E.C. it is now issued as a British Standard.

The same authors intend to supplement B.S. 600R, which is already well-known for its description of the statistical principle and methods used in Quality Control.

The new Standard is essentially a practical manual describing procedures which have been found acceptable when introducing and operating Quality Control methods as factory routine. Its major object is to assist production to a standard of quality, with the elimination of waste of labour and material.

The standard is divided into two parts. The first concerns the utilization of results of measurement (quantitative data) and is of particular interest to manufacturing industry wherever articles or components are produced in quantity with dimensional limits of accuracy.

The second part concerns the classification of a product by quality (qualitative data) and it is of use wherever sampling technique can be applied to regulate production.

The Standard will be of interest to those who are teaching the use of statistical methods.

Directions are given for the construction and interpretation of Control Charts appropriate to various types of process and examples of some of the different cases met in practice are given. Price: 10/6.

Phenolic Laminated Sheet. B.S. 2572 : 1955 specifies requirements for a number of types of phenolic laminated sheet which, in general, have good mechanical qualities, electrical insulating properties and resistance to corrosive influences.

The tests specified are designed to assess and differentiate between the types; they have not been selected in consideration of any particular use to which the material may be put.

The material is first divided into two groups: (a) where the mechanical properties in both directions are of the same order and (b) where they are markedly different. The first group is then sub-divided into four classes, according to whether the sheet is manufactured with an asbestos, cotton fabric, cellulose paper or wood veneer filler. Altogether 14 different types of material are covered.

The standard specifies requirements for: appearance, flatness, tolerance on thickness and marking of the material.

Additionally, limits are laid down for the following physical properties: Cross breaking strength, Impact strength, Water absorption, Electric strength (both flatwise and edgewise), Insulation resistance after immersion in water, and Crushing strength after heating.

Methods of test are specified in the Appendices. Attention is drawn to the optional use of the British Standard Certification mark. Price 4/-.

Methods for the Analysis of Aluminium and Aluminium Alloys. Part 6: Iron (volumetric titanous chloride method). Part 7: Zinc (zinc oxide method). (B.S. 1728: 1955). Part 6 relates to the volumetric determination of iron for use with alloys containing between 0·1 and 5·0 per cent iron.

Part 7 relates to the determination of zinc by the zinc oxide method, and is an additional method to those specified in Parts 3 and 4 (already issued). The method is for use with alloys having a zinc content of 2-15 per cent.

The methods specify the reagents to be used, recommended methods of sampling and text procedure. An indication of the reproducibility expected is given, and is derived from experiments carried out by a number of independent analysts. Price 2/-.

Classified Advertisements.

The rate for all classified advertisements is 6d. per word; in bold print 9d. per word; minimum order 6s. Box-number advertisements 1s. extra. Instructions, together with remittance, must be received not later than the 3rd of each month for advertisements to appear in the same month's issue.

APPOINTMENTS VACANT

ROCKET DIVISION.—Armstrong Siddeley Motors require Designers and Draughtsmen for exacting work in this division. Applicants must possess H.N.C. and/or have considerable drawing office experience. Apply, quoting Reference CG/RD5, Technical Personnel Manager, **Armstrong Siddeley Motors,** Coventry.

SENIOR PROJECT ENGINEER.—A vacancy is available for a Senior Project Engineer to head a group for the production of power from atomic energy. Applicants should have a background of experience, preferably in marine engineering, or, alternatively, experience on the mechanical side of the generation of power for land purposes. In addition, applicants should have scientific qualifications in the form of First-Class Honours Degree in Marine or Mechanical Engineering, together with a sound practical experience. This is an extremely important position and a good salary will be paid to a man meeting the stated requirements. Employment will be at Harwell initially. Box No. 26.

Armstrong Siddeley Motors, Coventry, have vacancies for

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for work on gas turbine aero engines. Apply to Reference D1, Personnel Manager, **Armstrong Siddeley Motors,** Coventry.

AN ENGINEER will be required shortly by leading Company for large Palm Oil Factory in Malaya. Qualifications required are either B.O.T. 1st Class Marine Certificate in Steam and Diesel, or A.M.I.Mech.E. with some practical experience with steam plant. Single preferred. Four figure starting salary with free accommodation, passages, transport allowance, commission on profits, and other benefits. Write with details to Box M.142, Haddon's, Salisbury Square, London, E.C.4.

A light Engineering Co., in West London has vacancies for **ENGINEERS** and **PHYSICISTS** in their Magnetic Recorder Design Laboratory. Preference will be given to applicants experienced in this work and who are capable of accepting responsibility. Salary will be according to age and experience. Write giving age and fullest details of experience to Box. 30.

TECHNICAL WRITERS.—The British Tabulating Machine Co. Ltd., Letchworth, Herts, invite applications from suitably qualified men who have completed their National Service and are interested in the preparation of Electro-Mechanical and Electronic Instruction Manuals for the Company's Electro-Mechanical and Electronic machines. Salary according to experience and qualifications. Pension and Sick Pay Schemes are in operation. Write giving personal particulars to the Personnel Officer (ref. E627D).

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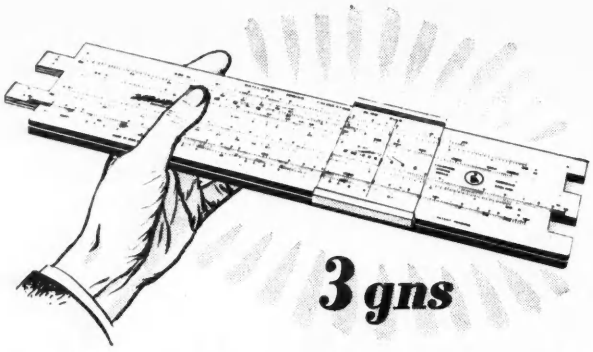

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100 YEARS OF ALUMINIUM AS AN ENGINEERING MATERIAL

To celebrate the Centenary of Aluminium as an engineering material, we shall be publishing a Supplement in the May 1955 issue of " The Engineers' Digest."

Articles specially written for our journal by technical experts of international reputation, will deal with the latest developments and topical problems concerning research and development, production and fabrication, as well as present and possible future applications of aluminium and its alloys.

The issue will include contributions on the following subjects:—

History and Trend of Future Developments of Aluminium Alloys.

British and Foreign Aluminium Standards.

Forging of Aluminium Alloys.

Welding of Aluminium Alloys.

Soldering of Aluminium.

Surface Finish of Aluminium.

Die-casting and Die-casting Machines.

Use of Aluminium in Bearing Alloys.

The Fatigue of Aluminium Alloys.

In addition, a " Pictorial History of Aluminium and its Alloys " will depict the most important stages in the history of the metal.

The Supplement will also be available on sale as a separately bound booklet under the title " 100 YEARS OF ALUMINIUM AS AN ENGINEERING MATERIAL " at 4s. 6d. per copy.

Total circulation will be not less than 10,000 copies.

Advertisements which can be, if desired, in editorial form, describing and illustrating the history of companies connected with the aluminium industry, their activities, and products, will be charged at our normal advertisement rates of £35 per page.

BOOKS RECEIVED

Steam, Air, and Gas Power. 5th edition. By William H. Severns, M.S., Howard E. Degler, M.E., M.S., and John C. Miles, M.E., M.S. 509 pages, 297 illustrations. Publishers: John Wiley & Sons, Inc., New York, and Chapman & Hall Ltd., 37 Essex Street, London, W.C.2. Price: 52/-.

In their new edition of this well known work, the authors have not only revised the fundamental material of earlier editions, so as to make it more useful for study and reference, but they have also shifted the emphasis of their discussion to reflect well established trends in current engineering practice. In doing so, they have incorporated in the book a great deal of valuable new material. Thus, for example, the discussion of gas turbines has been expanded into a new and comprehensive chapter; there is a completely new chapter on mechanical refrigeration; the scope of the section on air compressors has been broadened to include centrifugal and axial-flow types; specific heat information has been added in the thermodynamics chapter; and the chapter on fuels and combustion has been augmented by sections on the combustion of oils and gases.

Among other changes in this edition are new, effective illustrations; an extensive list of graded problems; and a large number of carefully selected and strategically placed illustrative examples.

In plan, the book follows the logical arrangement of earlier editions. The first two chapters serve to refresh the student's knowledge of basic definitions and to indicate the fields of heat-power engineering. The fundamentals of thermodynamics are presented in a clearly and concisely written chapter. After having covered the release of heat energy from fuels and the equipment necessary to convert it to power by means of basic steam cycles, the authors investigate other methods of energy conversion.

Safety in Industry. By D. I. Macfarlane. 71 pages, 82 illustrations. Publishers: Iliffe & Sons, Ltd., Dorset House, Stamford Street, London, S.E.1. Price: 7/6 (postage 3d.).

The protection of workers from disease and accidents is now recognised everywhere in industry as a matter of the utmost importance, and in all progressive organisations all necessary precautions are observed. Nevertheless, there remains the need for much more intensive propaganda on the subject. This useful book is a general introduction to the subject and gives details of a number of means whereby plant and premises can be made safer and personal protective measures more effective.

The special dangers of rotating machinery and the need for guards on presses and similar machines are well brought out. The control of dust and fumes is dealt with, and types of modern protective clothing, boots, and helmets surveyed. Prevention of skin diseases and protection of the eyes are considered, and there is a section on the precautions to be taken against harmful radiations arising from the industrial use of X-rays and radioactive substances. Finally, the important question of good lighting and flooring, both of which can contribute greatly to safety, are discussed.

This book will be of interest not only to employers, safety officers, and factory medical staffs, but also to workers exposed to these industrial hazards. Industrial executives in general should find it useful as summarising much important information in a clear and succinct form.

Theory of Structures. 4th Edition, 1954. By H. W. Coultas, M.Sc.(B'ham), B.Sc.(Leeds), M.I.Struct.E., A.I.Mech.E. 576 pp., 287 illustrations. Publishers: Sir Isaac Pitman & Sons, Ltd., Parker Street, Kingsway, London, W.C.2. Price: 25/-.

During the past few years, progress and development have been made in the theory, design, and fabrication of constructions designated pre-stressed concrete structures. At the same time, considerable research and experimental work have been undertaken, in order to determine the physical characteristics and mechanical properties of high-quality concrete, and the manufacture of this concrete for use in pre-stressed concrete constructions.

In the new edition of this well known book, a new chapter has been added, dealing with the fundamental principles of pre-stressed concrete design. In addition, some minor corrections have been made, and a number of up-to-date references given to journals presenting new theories and methods.

The book, which deals with the fundamental principles of the theory of structures, includes the various structural theories in steel and concrete necessary for students of civil and structural engineering and, as such, is intended to cover the syllabuses of the B.Sc.(Eng.) and the Inst.C.E., I.Mech.E., and I.Struct.E. examinations in this subject.

Drop, Press and Machine Forging. By J. C. Sharman, M.I.Prod.E. 163 pp., 124 illustrations. Publishers: The Machinery Publishing Co. Ltd., National House, West Street, Brighton 1. Price: 17/6.

This new addition to the Standard Reference Series issued by "Machinery" covers all aspects of modern hot forging by drop hammer, press, and forging machines, and includes chapters on:—Forging die design and making; forging machinery and its maintenance; types of furnace and methods of heating the billet and heat treatment of the forging; fettling, sand-blasting, pickling, and other subsequent treatment; inspection of the raw material and the finished forging; the layout of plant for efficient working; estimation for the manufacture of the dies and the forging operation.

The book is, in its field, comprehensive and merits especial praise for the excellence of the numerous photographs and drawings included.

LATEST INDUSTRIAL LITERATURE

1. Contour Marker for Pipes. Details are contained in a well conceived 8-page illustrated brochure of a contour marker which eliminates all cutting out of templates and marks all the way around pipes. The device consists of a frame or body, made from two channels in accurate alignment and fitted with a protractor or dial graduated on both sides. Attached to the protractor is a movable arm with three links, fitted at the end with a crayon for marking the pipes.

The marking on the dial is for angles or slopes, measured from a vertical line to the axis, while a sector is used for angles or slopes, measured from the axis. One side of the dial is marked in degrees, and the opposite side in inches to the foot. In operation, either side of the frame may be used, depending upon the direction of the line to be scribed. The centre-pin through the dial is tubular, and a "V" is cut at the opposite end, so that the tool can easily be centered over a reference line.

The standard model will work on any pipe from 1 to 18 in. in diameter; a larger model is available for pipes from 16 to 48 in. in diameter.

2. Heavy-Duty, Double-Acting Compressors. A neatly produced and illustrated brochure describes a new range of compressors of robust construction for continuous working on heavy service duty. These compressors are of double-acting crosshead design, operating at moderate speeds, and are available in a range of capacities from 500 to 10,000 cu ft per minute at 80 to 120 psig. In addition, there is a range of single-stage units of the new design.

Features of the new range of compressors include high efficiency, low maintenance, accessibility of working parts, dependability, economical operation, compactness, and smooth and quiet operation.

3. Butt-Welded High-Speed Tools. An illustrated leaflet gives details of standard shapes and prices of a comprehensive range of electrically butt-welded, high-speed tools, designed to permit the highest possible speeds and feeds. The cutting portion is of 10% cobalt high-speed steel, while electrical butt welding ensures full incorporation with the tough carbon-steel shank.

These tools are supplied hardened and tempered, ground to shape, and ready for use.

4. Atomic Models. In an interesting and very well produced and illustrated 12-page booklet, descriptions are given of a range of atomic models, designed for use in research and education to a scale of 0.8 in. = 1 Angstrom, and large enough to permit accurate quantitative work to be carried out. These models, which are believed to be a considerable advance on all previous designs, feature an arrangement of brass links and rubber collars for joining the models together, providing elastically-distortable valency angles which greatly extend their usefulness.

With these models, many molecules can be built, including those with strained rings, which cannot be built up with a rigid linking mechanism. The length of the link used ensures that the structures are sufficiently "open," to permit easy visual inspection; in particular, bond directions can be readily observed. At the same time, there is no sacrifice of free rotation about single bonds, and the link is strong enough to allow the largest molecules to be handled without falling apart. Furthermore, assembly is easy and rapid.

5. Heavy-Duty Oil-Cooled Welder. A leaflet describes and illustrates a heavy-duty, oil-cooled welder for operation from a.c. mains. This sturdy and compact unit, for all types and sizes of electrode up to 4 s.w.g., has an output of 20 to 300 A, with 85 V for striking the arc.

Output is clearly indicated on a simple scale, and welding current is adjusted by a simple hand-wheel, operating a moving iron reactance, providing infinite and sensitive adjustment throughout the entire welding range, thereby eliminating the use of change-over or selector switches, links, etc.

6. Materials-Handling Equipment. In an excellently produced and illustrated series of bulletins, neatly assembled in a loose-leaf folder, specifications are given of a comprehensive range of materials-handling equipment, including hand and electric hoists, hand-lift and electric trucks, and stacking machines.

The range of hoists embraces chain blocks and trolleys, portable jib cranes, slings, and wall hoists, while the range of trucks includes pallet trucks, platform trucks, fork-lift trucks, straddle trucks, and heavy-duty electric tractors, all with many outstanding features.

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THE BLUE PAGES

A QUICK GLANCE AT THE LATEST TECHNICAL DEVELOPMENTS THROUGHOUT THE WORLD

● *SELF-ADHESIVE TAPE CAPACITOR*

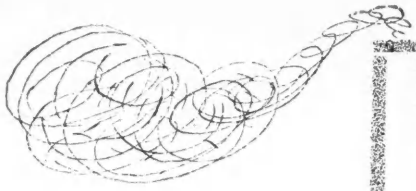
A self-adhesive tape capacitor has been developed by spraying electrically conductive solutions onto both sides of a tape. After drying, a layer of dielectric is sprayed on one side of the tape. The tape is then ready to be used as one element of the capacitor. The other element is a silver pattern, printed and fired on a ceramic wafer. The materials required for the manufacture of tape capacitors are a heat-resisting asbestos paper tape, silver flake, silicone resin, butyl cellosolve, a powdered high-K titanate body, n-hexane, and epoxide resin. The electrically conductive mixture, consisting of silver flake, silicone resin, and solvent, is sprayed on both sides of the tape. The dielectric is prepared as a slurry of pulverised high-K titanate and n-hexane, which is allowed to dry and is then ground in a ball mill. The powdered titanate is then mixed with epoxide resin and further ball-milled. This tacky mixture is then sprayed on the metallised tape in the required thickness. The silver pattern forming one electrode of the capacitor is applied to the wafer by means of a screen press and is then dried and fired onto the ceramic. The adhesive dielectric-coated tape is cut into squares slightly larger than the silver pattern and pressed onto it to form the other electrode. A narrow conductive strip is laid down between a contact on the edge of the wafer to serve as a terminal and the assembly is then cured at 225° C. Capacitors of higher value can be made by applying a number of layers of tape, one on top of the other.

● *SAFETY TEST FOR HYDRAULIC FLUIDS*

For many years petroleum oil has been used as the power transmission medium in hydraulically driven industrial machinery, as well as in ship-board hydraulic power systems. A recently published report points out that during the last two years an intensified search has been conducted for a fluid which has all the favourable properties of petroleum oil, but which is also fire- and explosion-resistant. Testing for explosion resistance, corrosion-inhibiting properties, and lubricity was conducted with a standard CFR Method 5 rating engine, which was modified as follows :—The compression ratio was increased by attaching a conical section to the end of the precombustion-chamber plug. An intermittent fuel-injection device was installed, so as to give an injection on three successive cycles, followed by 27 cycles with no injection. The evaluation may be conducted at temperatures other than the 212° F water temperature. Pressures may be determined by a pressure-sensitive pick-up and oscilloscope. If the compression ratio is increased, and the fluid is injected into the combustion chamber, the minimum compression ratio required for igniting the fluid can be determined. Correlative work with a compression ignition apparatus was carried out to determine the fire-resistant properties of hydraulic fluids when subjected to high-pressure air at 4000 psi. The test chamber is wetted with the fluid to be tested and, by means of a quick-opening valve, air at 4000 psi pressure is released into the chamber. Any explosion occurring is automatically recorded. A standard turbine-oil rust test modified for use with distilled water was employed for determining the water corrosion-inhibiting properties of the fluid.

● *SPECIAL APPARATUS FOR TWIST-DRILL RESEARCH*

A recent research report is concerned with an investigation into the mechanics of the actual cutting operation taking place along the cutting edges and under the chisel edge of a twist drill. Because the operating drill is rotating and buried in the workpiece, direct stroboscopic or high-speed photographic techniques could not be used. It was therefore decided to attempt to " freeze " the action by rapid stoppage of the relative motion between the drill and the workpiece. For this purpose, an extremely rapid deceleration is required to trap the actual operating conditions in the chips, and a special shear-pin deceleration apparatus had to be designed. In this apparatus the heavy drill and machine-spindle assembly is not stopped, but the relatively light workpiece and a spindle carrying it are accelerated to drill speeds. The apparatus consists of a rotor with a spring plunger, clamped to the drill, and a base assembly carrying the workpiece mounted in a spindle which is held in position by a notched, hardened high-speed steel shear pin. A compressed-air cushion is maintained under the workpiece spindle to relieve part of the drill-thrust load from the shear pin and to maintain the workpiece in contact with the drill during the axial-feed motion after the shear pin is broken. In operation, the drilled hole is started in the normal way, until the predetermined depth is reached. Then, a trigger



Meet Ethel Mary Sprott

It's mid-winter and she's sniffing because she's cold. She's fumbling because her fingers are frozen, she's fed up with the factory because it's like an ice-well. No heaters? Plenty! Trouble is, the building leaks heat like a sieve—especially through the roof! What's the answer? *

Meet Ethel Mary Sprott

It's mid-summer and she's sweating and swearing because she's hot. She's getting careless because she's drowsy. She's fed up because the factory's like an oven. What's the trouble? No windows or fans? Not on your life! Feel that roof. It's *baking* hot. No wonder production is slacking off. So what? So . . *

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on the side of the rotor is struck lightly with a steel bar, causing a spring-loaded plunger to be released so that it strikes a protruding lug on the workpiece spindle during the next revolution of the drill. This breaks the shear pin and virtually instantaneously accelerates the workpiece to the drill speed. As soon as the shear pin is broken, the drill-press motor is stopped, and after the spindle has come to rest, the drill is removed, leaving the chips attached to the bottom of the hole.

● *TECHNIQUE FOR MOULDING MELAMINE GLASS LAMINATES*

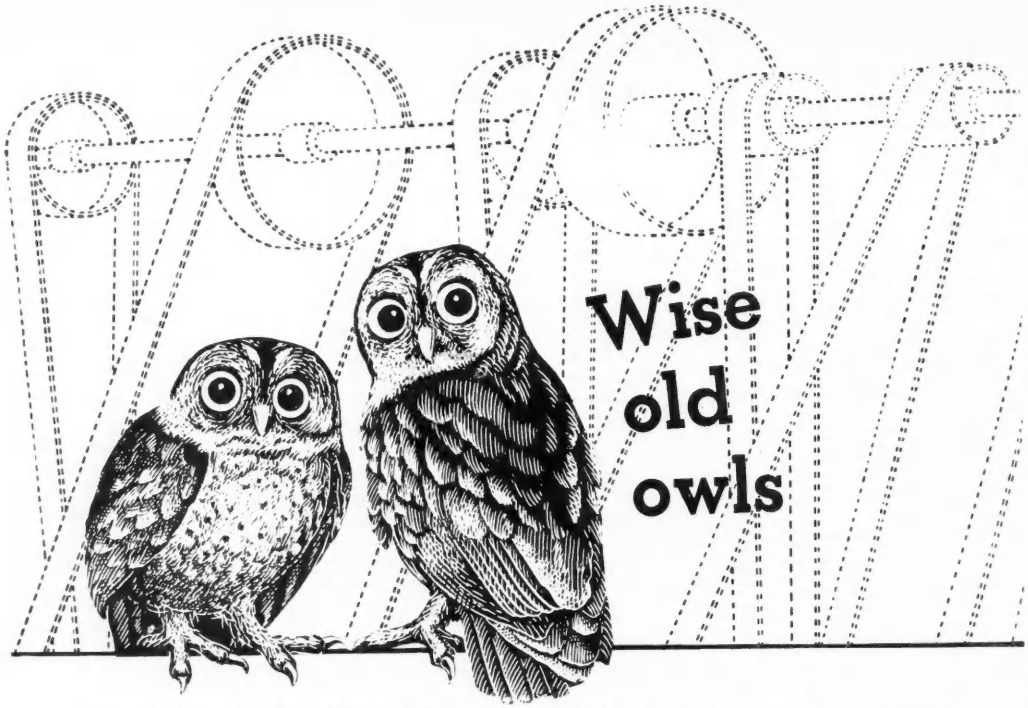
Although it is recognised that melamine glass laminates have many desirable qualities, they have not been found suitable for relatively large shapes or for production in small quantities, because of the expensive moulds and heavy presses required by high-pressure laminating techniques. It has now been announced that these limitations have been overcome by the development of a technique for moulding melamine glass-mat laminates at low pressures in the range from 150 to 200 psi. The low-pressure technique is claimed to be suitable for complex shapes as well as for flat sheets. Test results show that the flexural strength and water-absorption properties of filled laminates are in most cases superior to those of unfilled laminates. Glass content can be as low as 30% without sacrifice of physical properties. Laminates containing as much as 50% glass have higher flexural strength but are unsatisfactory because of their porosity and poor surface finish. For moulding complex shapes, the moulding pressure of 150 to 200 psi appears to be about the minimum pressure necessary to force resin through the mould cut-offs and to ensure that air is completely eliminated from the mould. It also seems that this pressure range represents the minimum required for developing optimum physical properties, where mats of chopped-glass preforms are used. It is significant that a reduction in moulding pressure does not affect physical properties of water absorption of melamine glass laminated sheet. Generally, melamine glass laminates offer excellent colour stability, alkali and chemical resistance, arc resistance, heat resistance, surface hardness, and abrasion resistance.

● *SHIPBOARD RADIO SEXTANT*

The development of a shipboard radio sextant which automatically tracks the sun even through rain, snow, and clouds has been announced. This new instrument is claimed to possess several important advantages over the hand-held optical sextant used at present, inasmuch as the new instrument can furnish information continuously from sunrise to sunset, it can operate under all weather conditions, and its calculations can be recorded automatically for future reference. The operating principle of the new sextant is based upon the fact that the sun radiates in the microwave spectrum. This thermal radiation, in the form of noise, is of very low level and was not detected until the advent of radar led to the development of receivers and antenna techniques for the low centimetre wavelength region. With the use of these techniques, an antenna and receiver for a wavelength of 1·25 cm was designed and is capable of detecting radiation from the sun in a 15 megacycle band width. A wavelength of 1·9 cm was chosen for the first model of the sextant, because at this wavelength atmospheric absorption during all weather conditions appeared to be sufficiently low. Also, it was short enough to allow an effective antenna power gain of × 6000 from a 30-in. parabolic reflector. In addition, an experimental sextant operating at a wavelength of 0·87 cm is being tested. The tests indicate that, with this wavelength, the radio sextant can be made to yield the altitude and bearing angles of the sun with a probable error of one minute of arc, except during severe rainstorms. With this wavelength an antenna of only one foot in diameter is required. The potentialities of the radio sextant for air navigation are being investigated.

● *VIBRATING IGNITER*

An interesting account of experiences with a novel type of igniter for ignitrons has just been published. As the report points out, two types of igniters are in use for single-anode mercury-arc rectifiers, the boron carbide igniter of the ignitron and the dielectric-shell igniter. It is stated that these two types have shortcomings which are difficult to overcome. Modern igniters make use of arc ignition at the delicate contact between the igniter surface and the mercury cathode, which may easily be violated by the powerful cathode spot during arc ignition. In contrast, the new igniter makes use of arc initiation which takes place at the breaking of electrical contact. When instantaneous values of current and terminal voltage of electrical contacts at this moment of breaking exceed 60 mA and 20 V, an arc can be ignited between the mercury pool cathode and the anode. The vibrating igniter consists of a steel rod with a needle tip at its end and, as it is driven by an electromagnet excited by the supply frequency and is polarised by a permanent magnet, its vibration is perfectly synchronised with the anode voltage. If the breaking phase of the contact between igniter tip and mercury surface is properly adjusted, stable arc initiation at the anode can be obtained. Wastage of the igniter tip is said to be negligibly small. Fluctuations of the level of the mercury pool are avoided by a special device. This consists of a metal disc with a number of small holes, located at the level of the mercury surface. When the whole surface is covered by a mercury layer, the cathode spot runs on this layer, eliminating wave motion on the pool surface.



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● *BERYLLIUM COPPER MOULDS FOR DIE-CASTING*

Many unconventional methods of mould construction have been suggested and tried with a view to reducing tooling costs in die-casting practice. Among them is the use of beryllium-copper mould cavities, which for certain types of casting are claimed to offer the most satisfactory and economical method of producing cavities. A recent report describes methods by which the fabrication of such moulds can be simplified and their service life considerably extended by minimising the erosion of the mould by the impinging metal in the casting process. Where intricate contours in three dimensions are to be provided in the mould cavity, it is often extremely difficult to produce these by means of a cutting tool. In such cases recourse is usually made to building up the cavity from several pieces, individually machined and then assembled to obtain the appropriate shape of cavity. This is, of course, a highly expensive procedure. According to the report mentioned, this difficulty can be overcome by producing the cavity by hobbing instead of by machining. In the conventional hobbing process, in which a hard-steel male pattern or hob is pressed under very high pressure into soft steel to form the die cavity, there is always the danger of hob breakage. This danger, it is claimed, can be eliminated by using beryllium copper as a mould material and by pouring the beryllium copper around the hob and then applying pressure. To prevent premature erosion of the mould by the impingement of the liquid metal, hard chromium plating of the cavity is recommended. While this method of producing mould cavities would seem to provide a solution to the problem of making cavities in the conventional way, it would appear that the now well-known method of spark machining will produce a superior result far more simply and economically.

● *CIRCUIT-BREAKING BY MEANS OF EXPLOSIVE CHARGES*

The most commonly used types of circuit-breakers are generally operated by electromagnetic means. It is known that electromagnetic devices have delay times of the order of 10 milliseconds, although by special means the delay time can be decreased to as little as 0·1 millisec. Still shorter delay times can, however, be obtained by using detonating explosive charges, which have the added advantages of a large energy release combined with small space requirements. The effect of a detonation naturally depends upon the exceedingly fast chemical decomposition of a detonant into gaseous reaction products, with the development of gas volumes which are a multiple of the volume of the detonant. In a recently developed system of utilising explosive charges for high-current breaking devices, detonators in the form of a copper cartridge of 7 mm diameter and 50 mm length are used. Such a cartridge may be made either to form part of the circuit to be broken, which is then interrupted by firing the charge, or the detonator may be used for triggering a spring-loaded circuit-breaker. It will be realised that the high-speed action of explosive-charge circuit-breakers is of particularly great value in the interruption of alternating current, as it makes possible the construction of synchronous breakers or fuses. Firing of the charge is effected by applying a sudden high-voltage current pulse. This can be produced by electronic means such as, for instance, a thyratron. In an experimental breaker with a total spring thrust of 445 kg, a total switching time of 2×10^{-4} sec was achieved with a detonating time of 2×10^{-5} sec and, by decreasing the mechanical inertia of the system, switching time could be lowered to as little as 1×10^{-4} sec. The cartridges can be easily replaced and are said to be insensitive to impact.

● *AUTOMATIC OZONE DETECTOR*

An automatic photoelectric instrument for continuous measurement of the ozone contained in atmospheric air at low altitudes has recently been developed. It is expected that this instrument, which is capable of determining extremely small ozone concentrations, will provide valuable information on air-mass movement and weather phenomena in general. Its reported use in connection with the investigations of the smog problem would appear to be another most timely application. Other possible applications include the correlation of the visible deterioration effects of ozone on rubber with accurate measurements of ozone concentration in the atmosphere. Interest in the deteriorating effect of ozone on rubber materials has greatly increased in recent years, as a result of the development of new synthetic elastomers with varying degrees of ozone resistance. Although ozone is only one of several agents influencing the deterioration of rubber materials under the influence of complex conditions of exposure to weather, it frequently proves to be the most severe. A simple method for accurate measurement of ozone concentration is therefore urgently needed. The new instrument incorporates a physical method which is based on the strong absorption characteristic of ozone in the spectral region between 2500 and 2600 Angstroms, known as the Hartley band. By using this spectral absorption, variations in the amount of ozone contained in the air are determined as a function of variations in the energy received by a detector from an ultraviolet source. For this purpose, a source of ultraviolet energy, such as low-pressure mercury-arc lamps, is positioned approximately 1500 ft from, and directed at, a sensitive photoelectric detector, containing a photo-multiplier connected with an amplifier and recorder.

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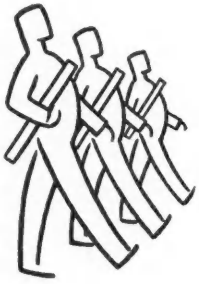

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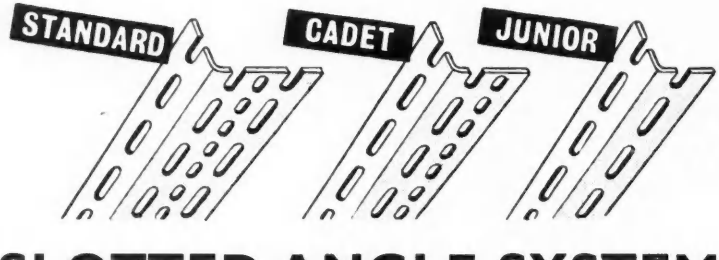

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● *CAGES FOR HIGH-SPEED ROLLER BEARINGS*

The importance of the cage or retainer as a component part of rolling contact bearings has been known for some time, owing to the failures experienced in high-speed roller bearings. Very little information on cage design and materials for such important applications as, for instance, turbojet engine bearings, is available in the literature. A recently published report on tests conducted on a number of different bearings is therefore of value. Two experimental investigations, one carried out for the purpose of evaluating the high-speed performance of six different roller-bearing cage designs (four experimental and two conventional) and one made for the purpose of assessing the merits of leaded brass and nodular iron as roller-bearing cage materials, were reported. The four experimental bearings used in the cage-design investigations had outer-race riding cages and inner-race guided rollers. This design was found to give the best overall performance. The superiority of this design over both the conventional inner-race riding-cage type and the conventional outer-race riding-cage type with outer-race guided rollers is considered to be the result of the relative ease of lubrication and cooling, and of adequate oil efflux paths, which minimise oil entrapment and churning losses. Data for four conventional bearings of the outer-race riding-cage type, of which two had lead-brass and two nodular-iron cages, were utilised for evaluating these cage materials. It is reported that nodular iron has a tendency to promote cage slip at high speeds, which is very harmful from the aspect of bearing wear. Bearings with nodular-iron cages therefore exhibited more wear of rollers and cages, especially in cage-roller pockets, than bearings with lead-brass cages.

● *BONDING SILICONE RUBBER TO METAL*

A new process for bonding silicone rubber to metal surfaces has just been patented. This process comprises three stages, i.e., phosphating the metal surface, contacting the phosphated surface with a layer of silicone rubber, and then applying heat and pressure. This method is claimed to be superior and cheaper than current techniques using special organic or inorganic adhesives, or priming the metal surfaces with silicone resin or orthosilicate compounds. Phosphating processes, which are extensively used, consist of the chemical treatment of iron, zinc, aluminium, and their alloys with dilute acid phosphate solutions saturated with a metal phosphate. The process is carried out by immersing the metal surface in the boiling phosphating solution or by brushing or spraying the phosphating solution onto the metal surface, so that an adherent phosphate film is produced. The silicone-rubber solid stock or paste may be applied by hand or by calendering or doctoring. Naturally, the manner of applying the silicone rubber in a given case will depend upon the contour of the metal surface and the physical characteristics of the silicone rubber employed. The rubber-coated surface is then subjected to heat and pressure in a press or autoclave for from one to ten minutes at 125 to 150° C, under a pressure of about 20 psi. This treatment vulcanises the silicone rubber and effects bonding between the rubber and the metal surface. It is usual to follow up vulcanisation by curing at 150 to 250° C. The silicone rubber may contain foaming agents, and articles consisting of foam silicone rubber may therefore be made to adhere to metal surfaces.

● *NEW PLASTIC FIBRE IN CONTINUOUS FILAMENT FORM*

A recent achievement of laboratory research is the development of a new synthetic-fibre tetrafluoroethylene polymer in continuous filament form. This is claimed to be one of the most highly chemically resistant fibres so far known and to have excellent stability at elevated temperatures. At present the fibre is produced on an experimental basis only. The new fibre exhibits the same chemical inertness and heat resistance as Teflon (tetrafluoroethylene resin) in the form of plastic materials, dispersions, finishes, and coated glass fabrics. The new fibre also exhibits some additional physical properties and, in fact, represents a new physical form of fluorocarbon compound. Its heat resistance, long flex life, good abrasion resistance, anti-stick properties, good strength, and low coefficient of friction should be of value in many gas- and liquid-filtration applications. In addition, it may prove useful in packings for shafts, valve stems, and reciprocating rods. Thus, it has been found that a packing of this material in a reciprocating pump handling CH_2O or H_2SO_4 at pressures in excess of 4000 psi was still satisfactory after 1800 hours of operation, while the best conventional packing lasted no more than 330 hours. Fabrics made of the new fibre are stated to be inherently non-wettable, even less so than polyethylene. When used in gas-filtration service, temperatures of 400 to 500° F appear admissible. There is no chemical degradation of the fibre up to 400 to 425° F. At about 550° F decomposition products appear at the rate of two parts per million per hour. At 800° F decomposition amounts to 1·5% weight loss per hour. A temperature of 525° F is generally considered the maximum long-time limit.

ERRATUM

In the Blue Page item on Self-Locking Retaining Rings on page 502 of our issue for December 1954, it was inadvertently stated that, for rings to be used on ½-in. shafts, a shear strength of 2500 psi was claimed. This should have read 2500 lb.

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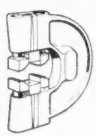

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